THE RESPONSE OF VEGETATION TO CHEMICAL AND HYDROLOGICAL GRADIENTS IN THE IMI FEN, HENRY COUNTY, INDIANA

A THESIS

SUBMITTED TO THE GRADUATE SCHOOL

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BY

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ABSTRACT

The relationship between fen vegetation and water and soil chemistry gradients in an alkaline slope fen was studied during the growing season of 2005. Owned by Irving Materials Inc. (IMI), the fen is a two hectare property in north-central Henry County, Indiana. The objectives of the study were (1) to conduct a floral inventory of the site and determine the floristic quality index for the site; (2) to visually characterize and stratify the site into areas of similar vegetation or community types; (3) to characterize relationships, if any, existing between vegetation and chemical and hydrological gradients; and (4) to quantify spatial and temporal patterns of ground water alkalinity throughout the fen. The floral inventory revealed 287 species, representing 180 genera in 79 families. Of the documented flora, 246 are native, 41 are adventives, and 20 represent Henry County records. The Floristic Quality Index and the mean Coefficient of Conservatism suggest that the site is of nature preserve quality and contains noteworthy remnants of the region's natural heritage. They also suggest that the adventives are having a minimal negative impact on the native flora. For quantitative vegetation analysis, fixed transects were monitored three times during the growing season (spring, summer, fall). Basic subsurface water chemistry and levels were monitored bi-weekly and 30 soil and 30 surface water samples (10 each to coordinate with the vegetation survey) were analyzed for over 35 physical parameters. In all cases, the parameters fell within the ranges of typical Midwestern fens, but most noticeably for calcium carbonate. Applying the Floristic Quality Assessment to the vegetation occurring along fixed transects, 26 species were identified with an importance value greater than one. Non-metric, multidimensional scaling analysis of fen species dominance delineate spatial and temporal patterns in vegetation. Joint plot vectors indicate the strength and direction of correlations between soil and water chemistry variables. Nine physical parameters were useful to separate vegetation into groups. The relationship between the plants and these nine parameters is described and discussed.

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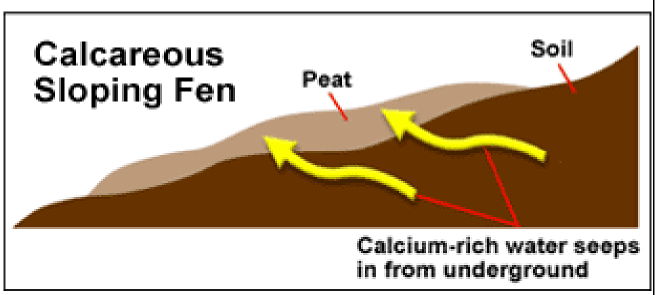
INTRODUCTION

Although fens are numerous throughout more northern latitudes and most fen research has been done in Canada and Northern Europe, this wetland type does occur in Indiana. Calcareous fens are one of the rarest wetland types in Indiana, especially in central Indiana, and no studies of the relationship between vegetation and the soil and water chemical gradients have been conducted in central Indiana. Since fens characteristically have an increased occurrence of rare and endangered plant species, an understanding of the response of vegetation to chemical and hydrological gradients is essential to protect and manage this valuable habitat type, thus making this study both necessary and valuable.

According to the U.S. Fish and Wildlife Service, wetlands are, as defined by Cowardin et al. (1979), “Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.” According to the Army Corps of Engineers (Environmental Laboratory 1987), wetlands must have the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the site is saturated with water or covered by shallow water at some time during the growing season of each year. Wetlands can be divided into two general categories depending on whether they are peatlands, such as the IMI fen, or not. Peatlands are ecosystems where organic material (peat) accumulates to a depth greater than 40 cm and the water table is at or near the soil surface (Gorham 1991, Mitsch & Gosselink 2000). Peatlands are further separated into two types: bogs and fens. Bogs are ombrotrophic (rain-fed) peatlands that receive nutrients only from precipitation, while fens are minerotrophic ecosystems receiving nutrients from ground water and surface water flow, as well as precipitation (Mitsch & Gosselink 2000). Amon et al. (2002) defines Midwestern fens as wetland communities that do not experience long-term inundation, have carbon accumulating substrates, are dominated by graminoid vegetation, and are dependent on ground water that moves through and maintains saturation in the root zone throughout the year.

Fens have a unique combination of structure, morphology, chemistry, hydrology, and vegetation. There are two types of fens based on topography and morphology. Slope fens occur in an area where underground water is discharged to the surface and then flows from a higher elevation to a lower elevation (Figure 1). Basin fens are frequently found on the shores of a lake and typically accumulate more peat than slope fens. The IMI fen is a slope fen. Fens usually occur in wet, seepage sites having an internal flow of ground water rich in calcium and magnesium bicarbonates and at

Figure 1. Diagram of a slope fen. *(From the Nature Conservancy, 2002.)*



times, calcium and magnesium sulfates. These compounds precipitate out at the surface, creating a harsh, alkaline soil (Mitsch & Gosselink 2000, Wisconsin Wetlands Association 2002). For this reason, fens are often described as being 'calcareous' fens.

Amon et al. (2002) lists five characteristics that define fens in the Midwest: water flow, saturation, level of inundation, water level fluctuation, and conductivity. First, the degree of water flow separates fens from bogs, wet meadows, and wet prairies. Fens have a higher water flow than bogs, wet meadows, and wet prairies, which typically have little to no water flow. Marshes, on the other hand, can have moderate to high water flow, similar to fens. The second distinguishing characteristic is saturation. Bogs and fens have a high saturation rate, while marshes have a moderate to high saturation rate, and wet prairies and wet meadows have a low saturation rate. The level of inundation is used separate marshes from other types of wetlands. Marshes have high inundation levels, while bogs, fens, wet meadows, and wet prairies typically have low inundation levels. The fourth characteristic, water level fluctuations, helps separates bogs and fens from all the other Midwestern wetland types. Bogs and fens have a nearly constant water level (hydroperiod), while other wetland types have continuous, often extreme, fluctuations in water level. The last characteristic defining fens in the Midwest is conductivity. Conductivity, along with water flow, is especially useful in separating bogs from fens. Bogs typically have lower conductivity levels than other wetlands. Because it is a minerotrophic ecosystem, conductivity is the most apparent parameter correlating fen-like plant communities with water chemistry (Amon et al. 2002).

Fens have a typical structure, based around an open marl zone where calcium-rich ground water discharge is highest. Marl, a substrate composed of calcareous clay among other materials, results from the precipitate of calcium and other minerals. As calcium-rich ground water reaches the surface, pressure is released, causing the calcium to come out of solution. Typically, the region around the marl zone has the highest alkalinity and the most-specialized plants (Choesin & Boerner, 2000).

Fens are mostly a northern hemisphere phenomenon. In North America fens occur in the northeastern United States, the Great Lakes region, and much of Canada (Environmental Protection Agency 2003, Mitch & Gosselink 2000). They are generally associated with low temperatures and short growing seasons, where ample precipitation and high humidity cause excessive moisture to accumulate. In Indiana, the greatest concentration of fens is through the northern tier of counties (Amon et al. 2002), but they do occur sporadically southward to the central region of the state.

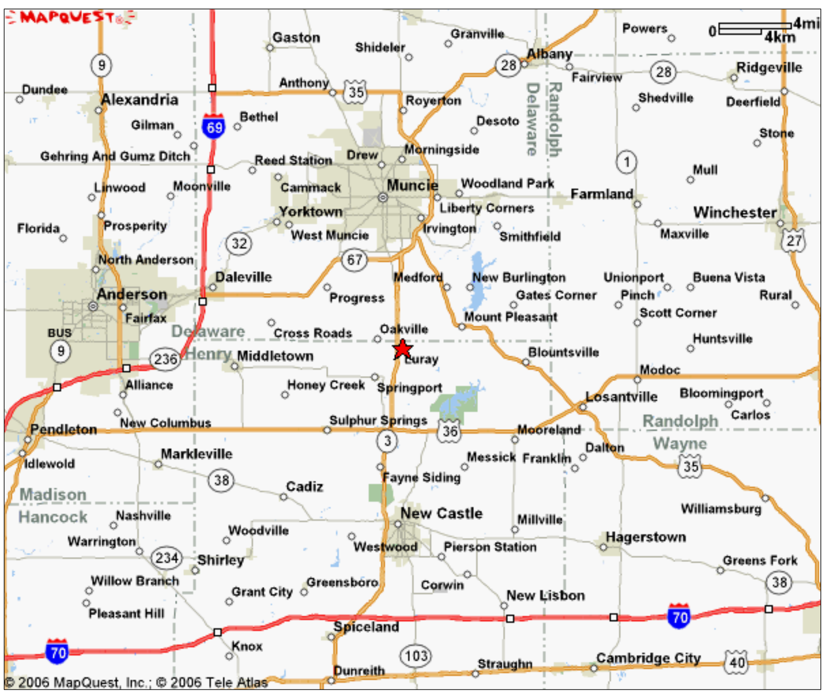
Objectives of the Research at the IMI Fen: Research at the IMI fen is important for three reasons. First, peatlands are rare in Indiana, especially in the central-Indiana Tipton Till Plain Natural Region. Since pre-settlement times, over 85% of Indiana's wetland areas have been destroyed (Dahl 1990, IDNR 1989), thus limiting opportunities to study fens. Secondly, fens have a unique, although not well understood, hydrology and chemistry among wetland types. This unique hydrology and chemistry makes fens home to many of Indiana's rare and endangered plant species and at the same time a place of high biodiversity. Thirdly, fens, especially in Indiana, have not been well researched, leaving a void in the scientific literature (Lee Casebier, IDNR, pers. commun.). This lack of information in the scientific literature includes not only the botanical aspects, but the physical parameters, both chemical and hydrological, of these unique peatlands. To date, in Indiana only Cowles Bog in Porter County and Cabin Creek

Raised Bog in Randolph County (both actually fens) have detailed floristic inventories be made (Wilcox et al. 1986, Ruch pers. commun.). Additionally, Cowles Bog is the only fen in Indiana in which some of the physical parameters of a fen been studied (Wilcox et al. 1986). Based on these reasons, this study of the fen on the IMI property was undertaken with four primary objectives: (1) to visually characterize and stratify the site into areas of similar vegetation or community types or polygons; (2) to characterize relationships, if any, that exist between the vegetation and chemical and hydrological gradients; (3) to quantify spatial and temporal patterns of ground water alkalinity throughout the fen; and (4) to conduct a floral inventory of the site and determine the floristic quality index for the site.

MATERIALS AND METHODS

Study Site: The IMI fen, an approximately two hectare wetland complex, is located in northern Henry County, Indiana, just east of State Road 3, near Luray (Figure 2).

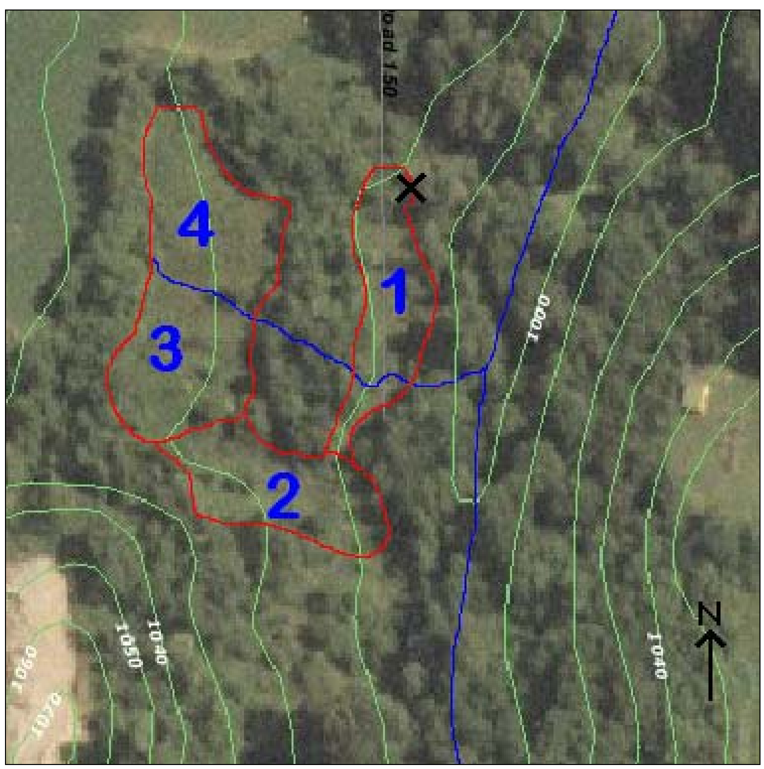
Figure 2. Location of the IMI wetland complex in northern Henry County. The red star indicates the location of the study site.



Aerial views of the fen are seen in Figures 3 & 4. The property is bordered on the south, the west, and the northwest by IMI, Inc., on the east by Brave Run, a creek which flows north (the creek is bordered on the east by private property), and on the northeast corner

Figure 3. A low magnification aerial view of the IMI wetland complex and surrounding lands. The red circle indicates the location of the study site.

Figure 4. Location of the four study sites (polygons). Polygons were determined visually based on distinctive vegetation types, location, topography, and apparent hydrology.

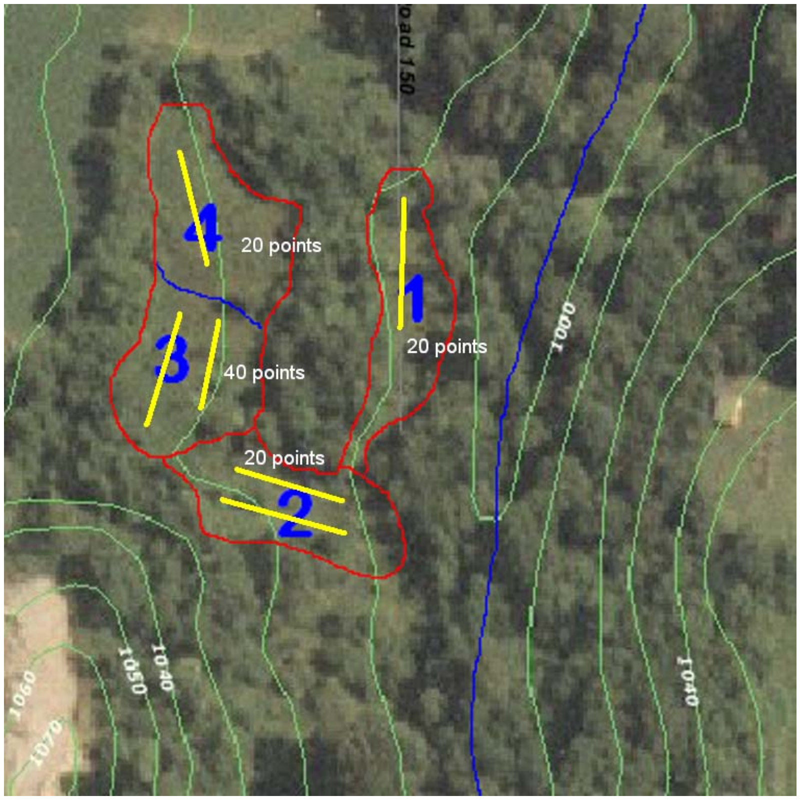


by private property. The private property along Brave Run and in the northeast is primarily woodlands. The entrance to the fen is in the northeast corner (indicated by an X in Figure 4).

Prior to the start of the research, the fen was visually divided into four areas (polygons) based on distinctive vegetation types, location, topography, and apparent hydrology (Figure 4). Polygon 1 occurs in the northeast corner of the fen complex and is at a lower elevation than the western half of the fen (polygons 3 & 4). It is separated from the western half by young mesic woodland, is bordered to the east by a wet woodland and Brave Run, and a shrub zone to the north and south readily provides natural boundaries. Polygon 1 is primarily a sedge meadow based on its vegetation and hydrology. Polygon 2 occurs in the south-central portion of the fen complex and is located on a slope that runs down hill from west to east. Woodlands surround most of Polygon 2. It is bordered on the east by a very moist woodland and Brave Run and on the west by a dry woodland and the quarry. The southern side of Polygon 2 borders the extension of the fen complex to the south (this area was not included in this study), and the northwest side of Polygon 2 borders Polygon 3. Polygon 3 occurs in the west-central region of the fen complex. It is bordered by young a mesic woodland to the east, a large marl run and Polygon 4 to the north, a dry woodland and the IMI quarry to the west, and Polygon 2 to the south. Polygon 3 was the wettest section of the fen, with thick deposits of peat. Polygon 4 occurs in the northwest corner of the fen complex. It is bordered by alfalfa fields to the north and west, the young mesic woodland to the east, and the open marl run and Polygon 3 to the south. Based on vegetation, Polygon 4 was a fen/sedge meadow community dominated by *Carex stricta*. Polygons 3 and 4 are located just west and up hill of Polygon 1, but are separated from Polygon 1 by the mesic woodland (Figure 4).

Transects: Transects were laid out in each polygon and were placed so as to adequately capture the representative floral community of each. Prominent features, such as trees, were used to mark the beginning of each transect and were tagged with tape for convenience of relocation. Points were randomly assigned along each transect using a random number table. The distance in meters between points along a transect was an integer from one through four. All other numbers on the random number table were discarded. Twenty points occur in one transect in Polygon 1, 20 points were split between two transects in Polygon 2 [with seven in the north transect of Polygon 2 and thirteen in the south transect], 40 points occur along two transects (e.g., twenty points to each transect) in Polygon 3 (due to its large size and diversity), and twenty points occur along one transect in Polygon 4 (Figure 5). Due to its large size and diversity, Polygon 3 contained 40 points. Each point was marked with a 2.5 x 60 cm white PVC pipe so that it could be located easily. A coin flip was used to establish if the plot fell to the right or left of the transect line. The point would always be on the corner of the plot closest to the beginning of the transect (i.e., if the plot fell to the right of the transect, the point would be in the back left corner plot). If the coin toss placed a plot on a trampled section of path during the first sampling period, the plot was shifted to the other side.

Figure 5. Location of the transects in each polygon.



Vegetative Sampling: The plots were sampled three times during the growing season: late spring/early summer, mid-summer, and late summer/early fall. Each sampling plot, 0.5 x 0.5 m or 0.25 m^2, was made with PVC pipe and elbow joints to connect them. For each plot, three types of data were recorded, i.e., plant species, percent cover class, and stem count. For stem counts, tussock forming species, such as *Carex stricta*, were counted as one stem per tussock. The percent cover classes system used was a modified Daubenmire scale (Table 1) (Daubenmire 1959). Due to over-lapping herbaceous layers, there is a possibility of greater than 100% cover.

Table 1. The percent cover classes using a modified Daubenmire scale.

Modified Daubenmire Scale	
1 to 7%	Cover Class 1
8 to 25%	Cover Class 2
26 to 50%	Cover Class 3
51 to 75%	Cover Class 4
76 to 93%	Cover Class 5
94 to 100%	Cover Class 6

Floristic Quality Assessment: The information obtained by vegetative sampling was entered into the Floristic Quality Assessment software program Version 1.0, Indiana Database. [This software program was developed by the Conservation Research Institution (Wilhlem & Masters 2000) in conjunction with Rothrock (2004).] The Indiana Database provides information on nativity, growth habit, and a coefficient of conservatism specific to Indiana. The floristic survey was used to calculate importance values. Importance values are a relative, unit-less term that expresses dominance on a scale from 0 to 100%, with the higher number reflecting a higher dominance. For this study, two parameters were combined to form an importance value, e.g., average cover class (the area covered by a given species) and frequency (how often a given species occurred along a transect). Importance values are similar to percentages, and like percentages, the importance values for all plants in an area sum to one hundred.

Water Chemistry: In order to examine water chemistry, thirteen monitoring wells were distributed throughout the fen to sample water flow for the entire research area. The wells, made from 5 cm diameter, 60 cm long PVC pipe, were sunken 50 cm into the ground with the aid of a soil auger. Numerous small slits were cut into the walls of the PVC wells with a table saw. These slits, 10-15 cm long, were located in the area 10 to 40 cm from the bottom of the pipe and allowed ground water inflow. The slits and open bottom end were covered with nylon mesh to prevent the wells from filling with sediment. The mesh was attached to the monitoring well with bailing wire. PVC caps were placed over the top of the monitoring wells to prevent the direct entry of rain water. Wells were assigned letters to allow for convenient labeling of samples. The location of the wells is listed below and seen in Figure 6.

A – Polygon 1, northeast corner of the polygon, near the entrance

B – Polygon 1, northwest corner of the polygon

C – Polygon 1, east side of the polygon, near the creek

D – Polygon 1, southeast side of the polygon, near the woods

E – Polygon 1, southwest side of the polygon

F – Polygon 2, east side of the polygon, the downhill side

G – Polygon 2, west side of the polygon, the uphill side

H – Polygon 3, south side of the polygon, in the *Symplocarpus foetidus* patch

I – Polygon 3, east side of the polygon

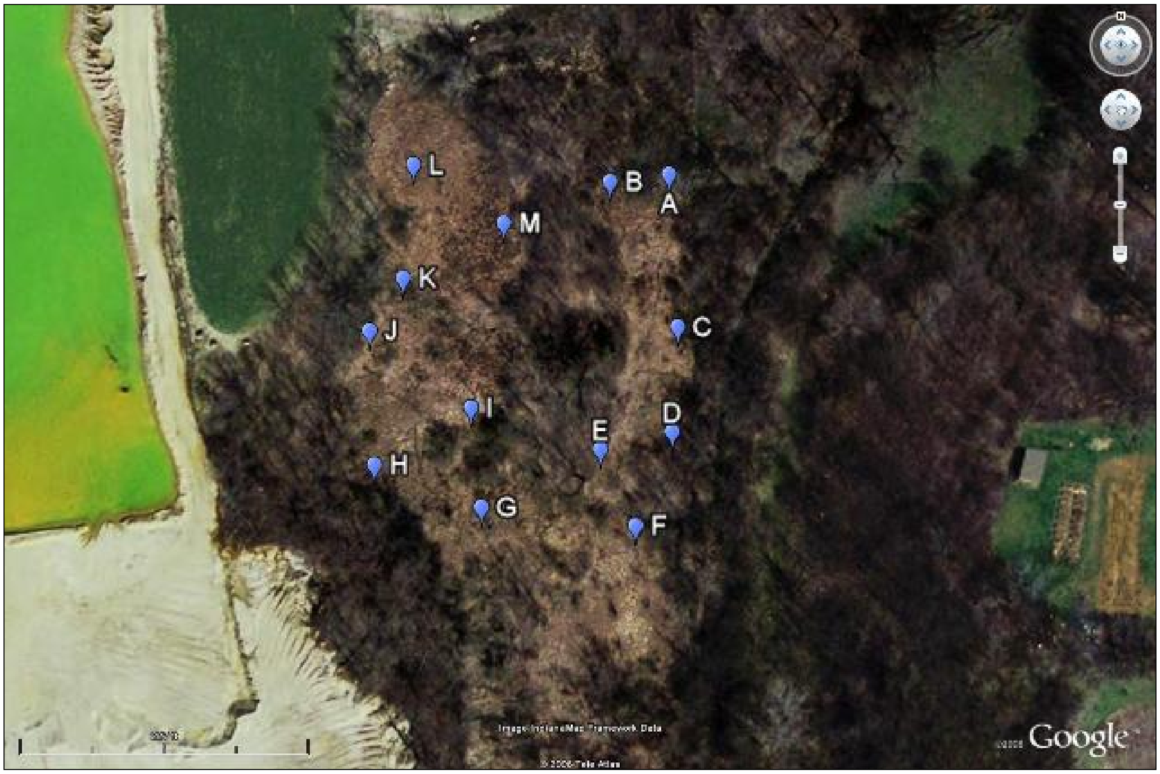
J – Polygon 3, west side of the polygon, behind the *Salix petiolaris* clump

K – Polygon 3, northwest corner of the polygon, in the marl run

L – Polygon 4, west side of the polygon, the uphill side

M – Polygon 4, east side of the polygon, the downhill side

Figure 6. Aerial view of the IMI fen showing the locations of the monitoring wells



From the monitoring wells, samples were collected twice a month for analysis, i.e., on or near the first and the fifteenth of the month. In the field, water samples were monitored for pH and conductivity using hand-held meters. A pH Testr 2TM by Oakton was used for pH testing and the DiST WP 3 by Hanna Instruments was used for conductivity testing.

Alkalinity: Alkalinity was measured using potentiometric titrations on samples from the monitoring wells. On the same day that pH and conductivity testing occurred, water samples were collected with plastic 25 mL pipets and placed in pre-washed 125 mL polyurethane bottles and transported to the Ball State University Chemistry laboratory on ice. Methyl Orange was used as a pH indicator since it fit nicely with a titration to a pH of 4.5 (Christian 2004). Two aliquots of 25 mL each were titrated and an average taken for each water sample. Titrations were done using HCl of 0.1022 molarity. Following is the calculation and preparation of the 0.1022 M HCl. The molarity of the HCl was first calibrated. The goal was to have a molarity of 0.1000, but a molarity sufficiently close would work if the molarity was known to a certain degree of certainty. The primary standard, THAM (tris(hydroxyl-methyl)aminomethane), was used in calibrating the HCl because it has an exact, known molecular weight of 121.14 grams per mole. The equation $M_1V_1 = M_2V_2$ was used in the first step to dilute a concentrated stock (16 M) of HCl. The equation with the components added was (16 M HCl)x(V_1) = (0.1 M HCl)x(1 Liter). The volume V_1 was the volume of concentrated (16 M) HCl placed in 1 liter of water; [0.1 L / 16 = 0.00625 mL]. This step yields approximately 0.1 M HCl. Step 2 was necessary to determine an exact value of molarity to 10^{-4}. The same equation was used in step 2, $M_1V_1 = M_2V_2$ rearranged as $M_2 = M_1V_1/V_2$. M_1V_1 was the moles of THAM, since molarity times volume is equal to moles. If an amount of THAM is weighed and divided by the known molecular weight of 121.14 g/mole, the yield is the number of moles of THAM. This was then dissolved into 50 mL of water and three drops of the indicator Methyl Orange was added. A burette was used to add 0.1 M HCl to the solution with THAM. The amount of the approximately 0.1 M HCl used was the V_2 of the equation. Dividing the moles of THAM by the volume of the approximately 0.1 M HCl gave the exact molarity of the HCl. This calibration was done three times and averaged together as shown below.

0.2331 g of THAM / 121.14 g/mole / 18.72 mL of HCl = 0.1028 M

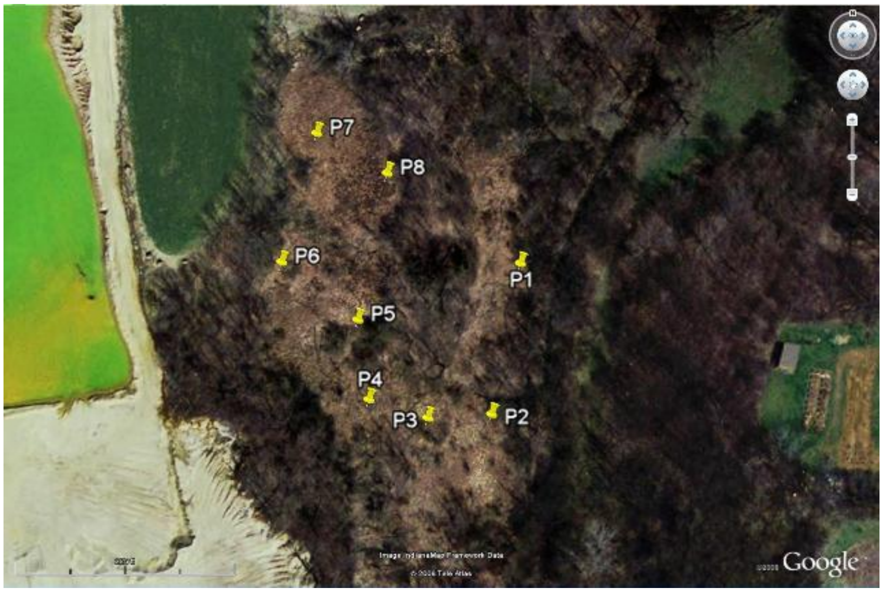
0.2566 g of THAM / 121.14 g/mole / 20.85 mL of HCl = 0.1016 M

0.2503 g of THAM / 121.14 g/mole / 20.02 mL of HCl = 0.1023 M

Average molarity of the HCl = 0.1022

Piezometers: Piezometers were placed around the study site to gauge ground water pressure, which causes the upward (discharge) or downward (recharge) movement of ground water, and to measure depth to free water. A nested piezometer consists of two wells of unequal length in close proximity, in which the difference between water depths is compared. Wells of 60 cm and 120 cm were used. Thin-walled metal conduit, 3.8 cm diameter, were capped on the bottom and driven into the ground with a sledge hammer, leaving 10 cm exposed. The caps were then driven off the bottom with a metal rod. The open, upper end was capped to prevent the entry of rain water. The piezometers were monitored twice a month, on or near the first and the fifteenth. Depth of water below surface was recorded by measuring the depth to the water level below the top of the well and then subtracting the height of the top of the well above the soil surface (e.g., 10 cm). Depth was recorded as centimeters below the surface, with negative numbers indicating that the water level was above the surface of the surrounding fen. Water level was determined by using a volt meter with leads attached to the end of a meter stick. The circuit would be completed when the electrodes on the tip of the meter stick made contact with the surface of the water. Following the advice of Dr. Hugh Brown (Department of Natural Resources and Environmental Management, Ball State University), eight nested piezometers were positioned throughout the study site. Their locations were as follows: Piezometer one was located on the east (downhill) side of Polygon 1; three were located in Polygon 2: Piezometer two on the east side (downhill), Piezometer three located midslope, and Piezometer four located on the west (uphill) side; two were located in Polygon 3; Piezometer five on the east side (downhill) and Piezometer six on the west (uphill) side; and two were located in Polygon 4: Piezometer seven on the east side (downhill) and Piezometer eight on the west (uphill) side (see Figure 7).

Figure 7. The location of piezometer wells at the IMI fen. Piezometer one = P1, Peizometer two = P2, etc. (See Figure 4 for location of polygons.)



Chemical Analysis: In order to ascertain relationships between physical parameters and the growth of individual plant species and plant communities, samples of soil and surface water were analyzed three times during the growing season, timed to correspond with vegetative sampling. A&L Great Lakes Laboratories, Fort Wayne, Indiana, performed the analyses. Soils samples were analyzed via the basic soil test packages S2 and S3. Soil test package S2 tested for organic matter, available phosphorus, exchangeable potassium, magnesium, calcium, soil pH, buffer pH, cation exchange capacity, percent base saturation of cation elements, soluble salts, and sodium. Basic soil test package S3 tested for measures of sulfur, zinc, manganese, iron, copper, and boron levels. Water samples were analyzed via the basic water test package for irrigation suitability (W2) which tested for sodium, calcium, magnesium, manganese, iron, chloride, conductivity, sulfate-sulfur, nitrate-nitrogen, pH, carbonate, bicarbonate, total alkalinity, phosphorus, potassium, boron, total dissolved solids, the sodium absorption ratio, BOD (biochemical oxygen demand) 5-day, and nitrogen in the form of ammonia. Ten water and ten soil samples were taken each of the three sampling periods. Two samples were taken from each of the four polygons, with additional samples from Polygon 3 due to its large size. Soil samples were taken from the A horizon below the O horizon (the organic layer). Enough soil was taken to fill a Ziploc plastic sandwich baggie. For water samples, enough water was taken to fill a 0.5 L (16.9 fl oz) water bottle. All samples were placed on ice and transported directly to A&L Great Lake Laboratories for analysis.

Inventory: During the 2004 and 2005 growing seasons, approximately one foray per week was made into the entire wetland complex. Forays were random but efforts were made to cover all areas. Voucher specimens for each species observed were collected and deposited in the Ball State University Herbarium (BSUH). Notes on vegetation consisted of a species list with visual estimates of the abundance of each species (see catalog of vascular plants, Appendix III). Additionally, seasonal changes in the dominant vegetation, based on phenology, were noted for the various habitats. Nomenclature follows the USDA Plants Database (USDA 2008). The floristic quality index (FQI) for the entire site was determined using the same computer software described previously for floristic quality assessment of vegetative sampling of the plots. This aspect of the program determines the number of native and adventive species, calculates a Floristic Quality Index (a standardized measure of site quality), and a mean Coefficient of Conservatism of the plant species present (Rothrock 2004). The Coefficient of Conservatism (also known as a C-value) is a number assigned by a committee of botanists and used to indicate how faithful a plant species is to a given habitat in a region (Swink and Wilhelm 1994). Adventives are assigned a C-value of zero, plants that are highly tolerant of disturbance have low C-values (1 to 3), and plants with a C-value of 8 to 10 (the maximum) grow only in high quality habitats.

Graph Ordination / Joint Plot / Statistics: Vegetation data was ordinated with the software program PC-ORD. . To simplify the analysis, a subset of dominant fen plant species was used. Sorensen's index was used as the distance measure in non-metric multi-dimensional scaling. Joint plots were produced with vectors that indicate direction and strength of correlations between vegetation and environmental variables. This type of data analysis allowed examination of the distribution of plant species within the various environmental gradients and determined which parameters were most closely associated with certain plant species.

RESULTS

Soil and Water Chemistry: The soil analysis from the IMI wetland complex is seen in Table 2. As expected for a calcareous fen, the soil chemistry was dominated by calcium. Each soil particle can hold a finite number of cations, and at the IMI fen calcium accounted for over ninety percent of the cations held by the soil. Magnesium was the second most frequent cation at about nine percent. Virtually no potassium or sodium was present in the soil, which creates a unique chemical stress on plants growing in the fen. Additionally, phosphorus was at very low levels in the soil, while other micronutrients, including boron, copper, iron, magnesium, and zinc, occurred at moderate to high levels. Soil pH was circum-neutral to basic with an average of 7.9. Cation Exchange Capacity was 71.7 millequivalents per 100 grams of soil.

Table 2. Soil Analysis from the IMI wetland complex.

Phosphorus	4.5	ppm	very low
Potassium	31.0	ppm	very low
Magnesium	428.0	ppm	very low
Calcium	15427.0	ppm	very high
Sodium	15.0	ppm	very low
Sulfur	32.0	ppm	very high
Zinc	4.0	ppm	moderate
Manganese	28.0	ppm	High
Iron	33.0	ppm	High
Copper	0.96	ppm	moderate
Boron	1.4	ppm	High

Calcium	90.7%	Percent Base Saturation
Magnesium	8.9%	
Potassium	0.3%	
Sodium	0.1%	
Ave. soil pH	7.9	
CEC	71.7	meq/100g

Chemical analysis of ground water samples showed that alkalinity was very high at the site. Average ground water samples had 593 milligrams of calcium carbonate per liter of water and typical values were between 300 to 500 mg $CaCO_3$ per liter. The median value for alkalinity was 387 mg $CaCO_3$ per liter. The mean calcium carbonate per liter of water was much higher than the median due to large outliers.

Ground water chemistry from the IMI wetland complex is seen in Table 3. Conductivity was consistently high for the bi-weekly measurements for ground water. In addition, the bi-weekly measurements of pH for ground water indicated that the four different polygons were typically circum-neutral to basic.

Table 3. Ground water chemistry data from the IMI wetland complex.

Top table – conductivity; Bottom table – pH.

Average Conductivity (muS)

	Spring	Summer	Fall
Area 1	683	762	542
Area 2	663	669	579
Area 3	493	475	452
Area 4	592	666	632

Average pH

	Spring	Summer	Fall
Area 1	7.3	7.3	7.5
Area 2	7.4	7.1	7.5
Area 3	7.4	7.3	7.5
Area 4	7.6	7.3	7.7

Inventory and Floristic Quality Index (FQI): An inventory for the entire IMI wetland complex, including the central and bordering woodlands, resulted in a total of 287 species collected, representing 180 genera from 79 families (Appendix 3). Thirty-six families were represented by only one species each. Four families, Asteraceae (37 spp.), Cyperaceae (27 spp.), Poaceae (28 spp.), and Rosaceae (17 spp.), contained 109 (38%) of the species documented. Fifty-eight percent of the species occur in only 12 families, e.g., Apiaceae (8 spp.), Caprifoliaceae (7 spp.), Fabaceae (8 spp.), Lamiaceae (8 spp.), Liliaceae (6 spp.), Polygonaceae (8 spp.), Ranunculaceae (6 spp.), and Scrophulariaceae (6 spp.), plus the four listed above.

A physiognomic analysis of the flora discloses that of the 287 species documented, 246, or 85.7%, are native and 41, or 14.3%, are exotic (adventive) (Appendix 4). Of the 246 native species, 54 species are woody (trees, shrubs, and vines), 141 species are herbaceous forbs and vines, 44 species are graminoids, and 7 are ferns and their allies (Appendix 4). Of the 41 adventive species, 9 species are woody (trees, shrubs, and vines), 21 are forbs, and 11 are grasses (Appendix 4). The FQI for all species (native plus exotic) was 57.3 and the mean Coefficients of Conservatism (C_{av}) for all species was 3.4. For just the native plants, the FQI = 61.9 and C_{av} = 3.9. The average Wetland Indicator Status for all species was -0.3 or a rating of Fac (+).

Of the 287 species documented, 11 have a Coefficient of Conservatism of 10, including *Carex buxbaumii*, *C. cryptolepis*, *Eleocharis elliptica*, *Lobelia kalmii*, *Muhlenbergia glomerata*, *Parnassia glauca*, *Ranunculus hispidus* var. *caricetorum*, *Rhynchospora capillacea*, *Solidago uliginosa*, *Spiranthes lucida*, and *Triglochin palustris*. (Although *Taxodium distichum* has a coefficient of conservatism of 10, it was not used to calculate FQI since it planted and out of it normal range.) Seven species have C values of 9, including *Carex sterilis*, *C. tetanica*, *Dasiphora fruticosa* var. *floribunda*, *Filipendula rubra*, *Lysimachia quadriflora*, *Oligoneuron riddellii*, and *Viola cucullata*.

Six species have C values of 8, including *Aureolaria virginica, Carex leptalea, Phlox maculata*, *Rudbeckia fulgida* var. *sullivantii*, *Solidago patula*, and *Symplocarpus foetidus* (see Ruch et al. 2008). Additionally, 13 species have C = 7.

Based upon the Indiana Natural Heritage Data Center's records for Henry County and the plants reported at Wilbur Wright Fish and Wildlife Area (Ruch et al. 2002), 20 species documented at the wetland complex represent Henry County records. Lastly, using the list on the Divisions of Nature Preserves, Indiana Department of Natural Resources website (2007), the status of several plants at the IMI wetland complex is as follows: Rare: *Spiranthes lucida* and *Triglochin palustre*; Watch List: *Filipendula rubra*, *Hydrastis canadensis*, and *Selaginella apoda*.

Importance Values: Both environmental and plant data were compared to each other using multivariate statistics (see below). Therefore, to simplify the analysis, a selected subset of fen plant species was used. Of all the plants that occurred within a plot, twenty-six species had an importance value (IV) greater than one (Table 4 and Appendix 2) when the importance values for the four polygons was averaged. The most dominant (IV) plant at the IMI fen was the sedge *Carex stricta*. It was the most dominant plant in each of the four polygons and was the characteristic plant of the fen. The generalist wetland species *Impatiens capensis* was the second most dominant (IV) species, followed by the quality fen species *Symphyotrichum puniceum, Solidago patula,* and *Pycnanthemum virginianum* (Table 4). Based on hydrology and visual examination of the flora biodiversity, Polygon 1 was characterized as a sedge meadow and the two species with highest importance values were the sedges *Carex stricta* and *Carex sterilis* (Appendix 2). Despite the presence of shrubby cinquefoil, most of the plants in Polygon

1 had a low plant profile, possibly indicative of harsh or stressful growing conditions. Polygon 2, located at the southern end of the site, was dominated by a combination of *Carex stricta* and *Pycnanthemum virginianum* (Appendix 2). Polygon 3, the wettest zone of the site, was dominated by *Carex stricta* and *Impatiens capensis* (Appendix 2). Polygon 3 also had the tallest plant profile with *Impatiens capensis* and *Eupatoriadelphus maculatus* growing over five feet tall. Polygon 4 had the highest importance value for *Carex stricta* and had the lowest biodiversity of the four polygons. In Polygon 4 *Carex stricta* had an average importance value of 25.22, while it only had values of 15.08, 12.07, and 10.70 in Polygons 3, 2 and 1 respectively (Appendix 2).

Table 4. Species from the plot survey having an importance value greater than 1. The importance value (IV) represents the average IV from the four plots.

Species	**IV avg**
Carex stricta	15.84
Impatiens capensis	7.20
Symphyotrichum puniceum	6.82
Solidago patula	5.28
Pycnanthemum virginianum	4.21
Thelypteris palustris	3.52
Eupatoriadelphus maculatus	3.15
Dasiphora fruticosa	2.69
Packera aurea	2.60
Leersia oryzoides	2.13
Carex sterilis	2.09
Equisetum arvense	1.96
Oxypolis rigidior	1.87

Species	**IV avg**
Pilea fontana	1.79
Eupatorium perfoliatum	1.58
Rudbeckia fulgida	1.58
Filipendula rubra	1.51
Eleocharis elliptica	1.35
Viola cuculata	1.33
Cuscuta gronovii	1.32
Glyceria striata	1.31
Lycopus uniflorus	1.26
Lysimachia quadriflora	1.19
Equisetum hyemale	1.07
Salix petiolaris	1.04
Galium triflorum	1.01

Graph Ordination / Joint Plot: Both environmental and plant data were compared to each other using multivariate statistics. To simplify the analysis, a selected subset of fen plant species was used. The type of multivariate statistics used was non-metric, multidimensional scaling, using the Sorensen's index, and the computer program PC-ORD performed the analysis. This type of data analysis allowed examination of the distribution of plant species within the various environmental gradients and determined which parameters were most closely associated with certain plant species. The four types of variables evaluated in terms of the two graph axes were plot location, time, environmental variables, and plant species.

Non-metric Multidimensional Scaling using PC-ORD revealed an interesting pattern to the environmental and vegetative data. The wetland complex split into two sections, Polygons 1 and 2 (the eastern and southern sections) and Polygons 3 and 4 (the western section) (Figure 8). The first digit after plot referred to the specific area of the fen. The second digit referred to which sampling period it came, i.e., spring, summer, or fall.

Trends throughout the Growing Season: Polygon 2, 3, & 4 showed a similar pattern as the growing season progressed, showing a negative correlation with both the X-axis and the Y-axis (Figures 8 & 9). In addition to becoming wetter as the season progressed, they also increased in soil cation exchange capacity and decreased in soil manganese (Figure 9). Polygon 1 showed a different trend, increasing along the X-axis, but decreasing along the Y-axis (Figure 9). Not only did the area become drier as the season progressed, but decreased in pH and soil cation exchange capacity, and increased in surface water magnesium, potassium, calcium, and in surface water conductivity (Figure 8 and Appendix 1).

Figure 8. Trends both in time and plot location. For each point on the figure (plot), the first number indicates the plot and the second number indicates the sample period, i.e., 1 = spring, 2 = summer, and 3 = fall.

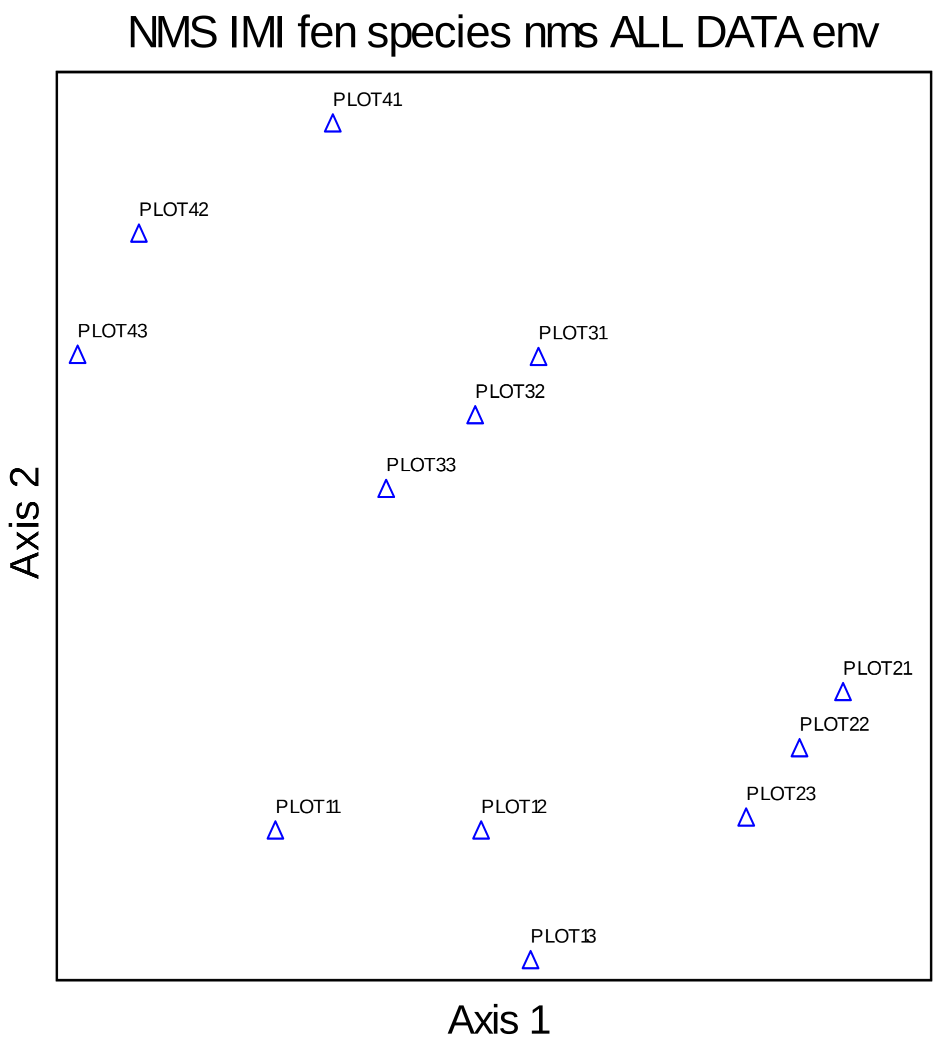
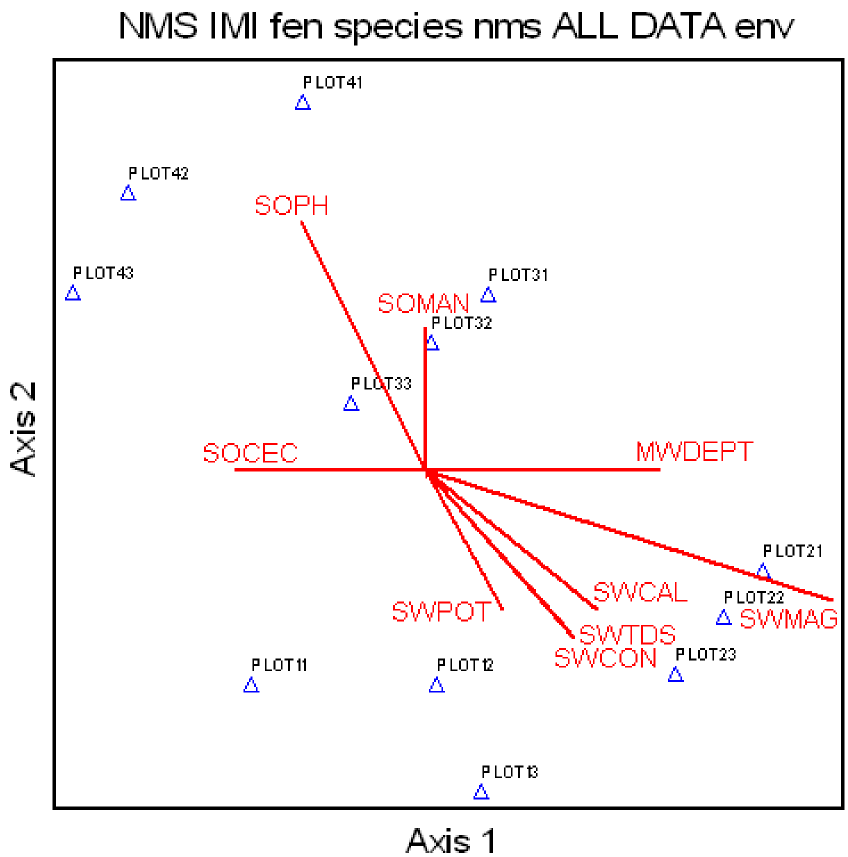


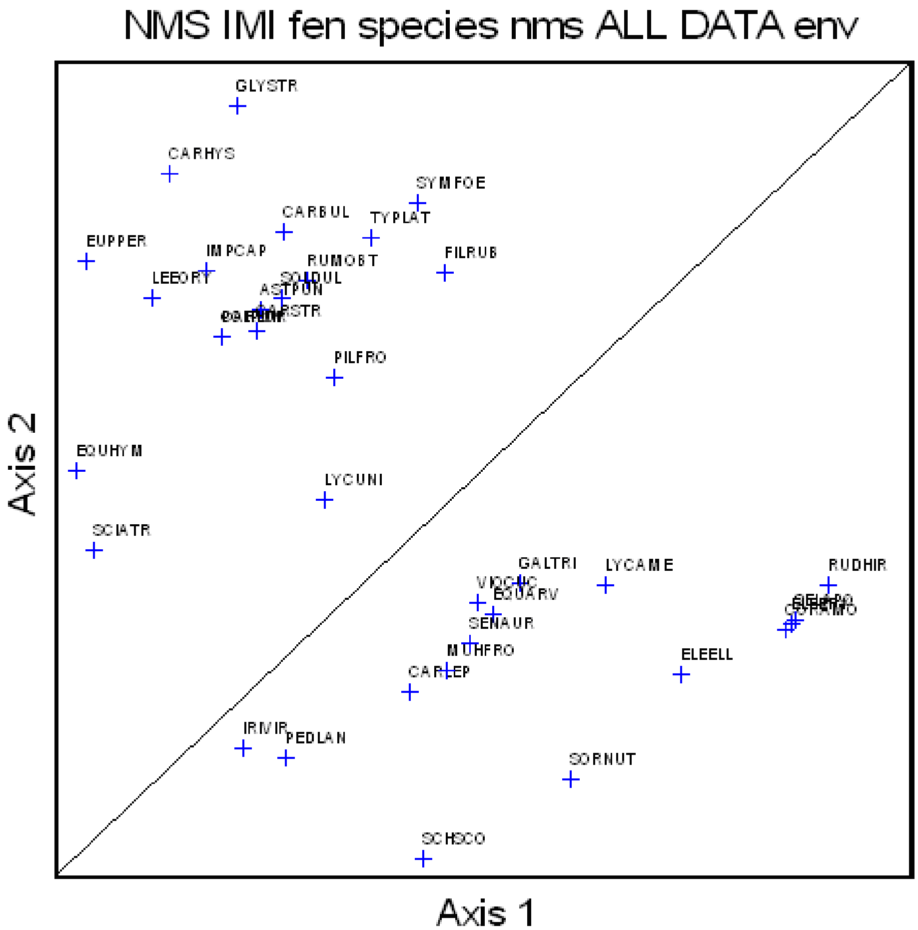
Figure 9. Trends throughout the growing season between the physical parameters measures and plot locations.



SOPH	soil pH
SOMAN	soil manganese
MWDEPT	monitoring well depth
SWMAG	surface water magnesium
SWCAL	surface water calcium
SWTDS	surface water total desolved solids
SWCON	surface water conductivity
SWPOT	surface water potassium
SOCEC	soil water cation exchange capacity

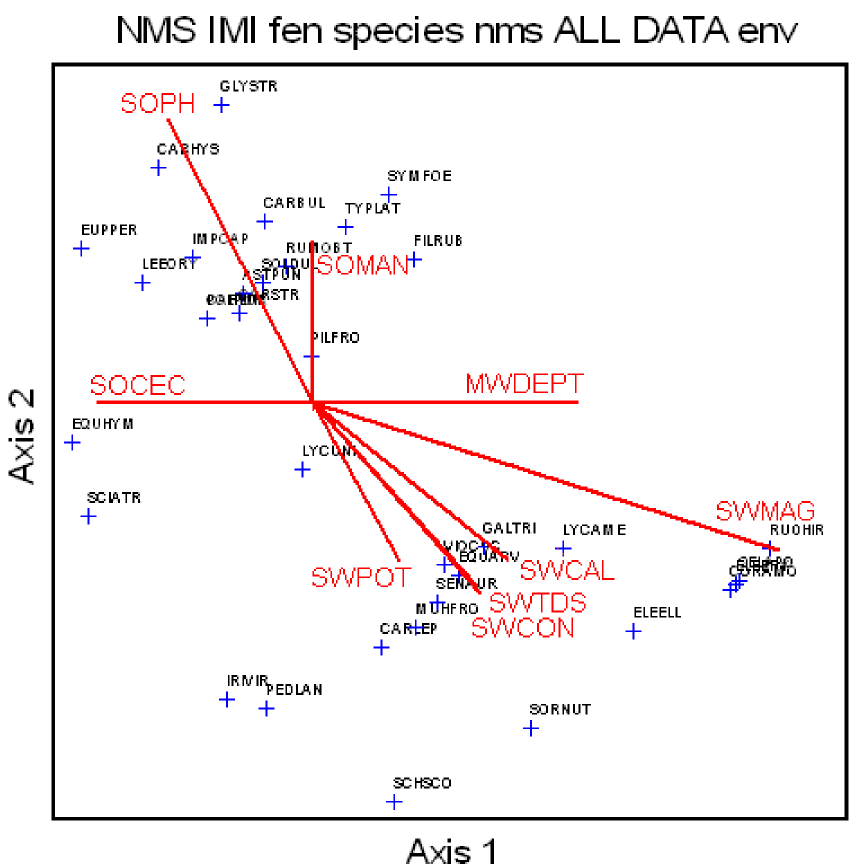
Plant Distribution: When comparing floral distribution throughout the fen, the plant species split almost evenly into two groups (Figure 10). Polygons 3 and 4, divided only by the marl run, plotted out together, while Polygons 1 and 2 grouped together on the joint plot. (See Figure 10 and compare to Figure 8 for plot locations). Some fen or wetland plants with a particularly strong correlation to Polygon 3 and 4 were *Cardamine bulbosa*, *Symphyotrichum puniceum* , *Carex stricta*, *Eupatorium perfoliatum*, *Impatiens capensis,* and *Filipendula rubra*. Some fen or wetland plants with a strong correlation with Polygon 1 and 2 were *Eleocharis elliptica, Equisetum arvense, Galium triflorum, Packera aurea,* and *Viola cucullata*.

Figure 10. Plant distribution within the multivariate matrix. Identification of plant abbreviations: ASTPUN = *Symphyotrichum puniceum*, CARBUL = *Cardamine bulbosa*, CARHYS = *Carex hystericina*, CARLEP = *Carex leptalea*, CARLUR = *Carex lurida*, CARSTR = *Carex stricta*, CORAMO = *Cornus obliquua*, ELEELL = *Eleocharis elliptica*, ELEERY = *Eleocharis erythropoda*, EQUARV = *Equisetum arvensis*, EQUHYM = *Equisetum hyemale*, EUPPER = *Eupatorium perfoliatum*, FILRUB = *Filipendula rubra*, GALTRI = *Galium triflorum*, GLYSTR = *Glyceria striata*, IMPCAP = *Impatiens capensis*, IRIVIR = *Iris virginica*, LEEORY = *Leersia oryzoides*, LYCAME = *Lycopus americanus*, LYCUNI = *Lycopus uniflorus*, MUHFRO = *Muhlenbergia frondosa*, PEDLAN = *Pedicularis lanceolata*, PILFRO = *Pilea fontana*, POLPUN = *Polygonum punctatum*, RUDHIR = *Rudbeckia hirta*, RUMOBT = *Rumex obtusifolius*, SCHSCO = *Schizachyrium scoparium*, SCIATR = *Scirpus atrovirens*, SELAPO = *Selaginella apoda*, SENAUR = *Packera aurea,* SOLDUL = *Solanum dulcamara*, SORNUT = *Sorghastrum nutans*, SYMFOE = *Symplocarpus foetidus*, TYPLAT = *Typha latifolia*, VIOCUC = *Viola cucullata*.



Species Distribution in Relation to Physical Parameters: Certain plants showed a strong correlation with certain environmental variables (Figure 11). For example, *Eleocharis elliptica*, *Equisetum arvense, Galium triflorum, Packera aurea,* and *Viola cucullata* all showed a correlation with an increase in conductivity, total dissolved solids, soil magnesium, and surface water potassium and with a decrease in soil manganese and soil cation exchange capacity. Especially strong was the correlation with an increase in calcium, the decrease of water levels, and a more neutral pH. Showing the opposite pattern, *Cardamine bulbosa*, *Symphyotrichum puniceum* , *Carex stricta*, *Eupatorium* *perfoliatum*, and *Impatiens capensis* showed a correlation with decrease in calcium, conductivity, total dissolved solids, soil magnesium, surface water potassium, and an increase in soil manganese, soil cation exchange capacity, with more available moisture, and a higher (more alkaline) pH.

Figure 11. Species distribution correlated to physical parameters. (For identification of plant abbreviations, see Figure 10.)



SOPH	soil pH
SOMAN	soil manganese
MWDEPT	monitoring well depth
SWMAG	surface water magnesium
SWCAL	surface water calcium
SWTDS	surface water total desolved solids
SWCON	surface water conductivity
SWPOT	surface water potassium
SOCEC	soil water cation exchange capacity

Individual Species: Below are the results of the multivariate statistics for the selected thirty-five individual species when compared to the environmental parameters that were measured in the study area.

Cardamine bulbosa, *Rumex obtusifolius*, and *Typha latifolia*: These species had a strong positive correlation with the levels of soil manganese. They exhibited a strong negative correlation with the level of potassium, the level of calcium, the level of magnesium, conductivity, and total dissolved solids in surface water. They had a positive correlation with the soil pH, thus preferring basic soils. However, no correlation was observed with monitoring well depth (depth of the water table) or the soil cation exchange capacity.

Filipendula rubra and *Symplocarpus foetidus*: These herbaceous species exhibited very similar characteristics to the species in the group immediately above. Oddly, these wetland species showed zero to only a slight positive correlation with monitoring well depth (depth of the water table). They had a positive correlation with soil pH, preferring more basic soil, and a strong positive correlation with the levels of manganese in the soil. *Symplocarpus foetidus* had a negative correlation with the levels of calcium and potassium in surface water, and with total dissolved solids and conductivity in surface water. They exhibited a slight positive correlation with the level of surface water magnesium, and a slight negative correlation with cation exchange capacity in the soil.

Carex hystericina and *Glyceria striata*: These two graminoid species had a very strong positive correlation with both the level of manganese in the soil and with soil pH, apparently preferring basic soil conditions. Both exhibit a positive correlation with the cation exchange capacity of the soil. Both species showed a very strong negative correlation with the levels of calcium, magnesium, and potassium in the surface water, as well as total dissolved solids and overall conductivity of the surface water. Lastly, both species exhibited a negative correlation with monitoring well depth, indicating a preference for a shallow water table.

Carex leptalea, *Equisetum arvense*, *Galium triflorum*, *Muhlenbergia mexicana*, *Packera aurea*, and *Viola cuculata*: These species exhibited a negative correlation to soil manganese and a strong negative correlation to soil pH, being found more frequently in more neutral soils. In addition, they had a positive correlation with the levels of magnesium in surface water and a strong positive correlation with the levels of calcium, potassium, total dissolved solids, and conductivity in the surface water.

Carex lurida, *Carex stricta*, *Lycopus americanus*, *Polygonum punctatum*, *Solanum dulcamara*, and *Symphyotrichum puniceum*: These species exhibited a positive correlation with soil pH, preferring more basic soil, and a positive correlation with the soil cation exchange capacity and the levels of manganese in the soil. In addition, they had a negative correlation with the depth to the water table, preferring a shallower water table, and a negative correlation with the levels of magnesium, calcium, and potassium in surface water, and the level of total dissolved solids and conductivity in surface water.

Cornus obliqua, *Eleocharis elliptica*, *Eleocharis erythropoda*, *Rudbeckia hirta*, and *Selaginella apoda*: These species exhibited a negative correlation with levels of manganese and the cation exchange capacity in the soil, and had a strong negative correlation with the pH of the soil. In addition, they had a positive correlation with the depth of the water table, occurring most frequently where the water table was further from the surface. They also had a strong positive correlation with the levels of magnesium, calcium, potassium, total dissolved solids, and conductivity in surface water.

Schizachyrium scoparium and *Sorghastrum nutans*: These grasses species exhibited very similar characteristics to the species in the group immediately above. They showed a strong negative correlation with soil manganese and a negative correlation with the soil cation exchange capacity, especially *S. nutans*. Additionally, they had a strong negative correlation with soil pH, such that, as the soil became more basic the frequency of these species decreased. They exhibited a positive correlation with the depth of the water table, such that, as the depth from the surface to the water table increased, so did the frequency of these grasses. They also had a positive correlation with the levels of magnesium in surface water, and had a strong positive correlation with the levels of calcium, potassium, total dissolved solids, and conductivity in surface water. Both are prairie species that appears to prefer the drier and more neutral areas within the fen.

Equisetum hyemale and *Scirpus atrovirens*: Both species exhibited a very strong negative correlation with the monitoring well depth, being found very infrequently when the water table was not at or near the surface. Likewise, both species showed a strong negative correlation to the level of soil water magnesium, thus decreasing in frequency with an increase in surface water magnesium. They also had a slight negative correlation to the level of soil manganese. Both species exhibited a very strong positive correlation with the soil cation exchange capacity, being found most frequently when the soil cation exchange capacity was the highest. Although *E. hyemale* showed no correlation with calcium, potassium, conductivity, and the total dissolved solids in surface water, *S.*

atrovirens exhibited a slight positive correlation with the physical parameters. Similarly, *E. hyemale* showed no correlation with soil pH, *S. atrovirens* had a slight negative correlation, thus preferring slightly less basic soils.

Eupatorium perfoliatum, *Impatiens capensis* and *Leersia oryzoides*: These species had strong negative correlations with the levels of magnesium, potassium, and calcium in surface waters, and with the surface water conductivity and total dissolved solids. They exhibited a negative correlation with the depth of the water table, occurring most frequently where the surface of the water table was closest to the surface, and had a positive correlation with soil pH, soil manganese, and the soil cation exchange capacity.

Iris virginica and *Pedicularis lanceolata*: Both of these species exhibited a strong negative correlation with soil pH, indicating a preference for a more neutral soil, but surprisingly both had a positive correlation with levels of calcium in the surface water. They showed a negative correlation with soil manganese, but had strong positive correlations with the levels of potassium in surface water, surface water total dissolved solids, and conductivity. No correlation was observed with soil cation exchange capacity, surface water magnesium, or the depth of the water table.

Lycopus uniflorus: This species exhibited a slight negative correlation with the level of manganese in the soil and the soil pH, preferring the more neutral areas of the fen. No correlations were observed with the level of magnesium in the surface water, the cation exchange capacity of the soil, or the depth of the water table, although it was found in areas with a higher water table. A slight positive correlation was observed with levels of calcium and potassium in surface water, and with surface water conductivity and total dissolved solids.

Pilea fontana: This species exhibited a slight positive correlation in increasing levels of manganese in the soil and soil pH. However, no other correlations were observed. It was somewhat surprising that no correlation to water table depth was seen, since this species is noted for occurring in very wet, springy habitats.

DISCUSSION

Inventory: The vascular flora at the IMI wetland complex includes the same core of plants, and consequently plant families, reported for other sites in east central Indiana (Rothrock et al. 1993; Rothrock 1997; Ruch et al. 1998, 2002, 2004, 2007, 2008a; Stonehouse et al. 2003). However, due to the fens and sedge meadows at IMI, grasses and sedges composed a higher percentage of the species, about 20%, when compared to the other sites. The 12 plant families, accounting for more than 50% of the plants reported at IMI and all the sites referred to above, are the Apiaceae, Asteraceae, Brassicaceae, Caprifoliaceae, Cyperaceae, Fabaceae, Lamiaceae, Liliaceae, Poaceae, Polygonaceae, Ranunculaceae, and Rosaceae.

The floristic quality index (FQI) for the native flora at the IMI wetland complex was 61.9, with a mean coefficient of conservatism (C_{av}) of 3.9. These numbers indicate that the site contains noteworthy remnants of a region's natural heritage (Rothrock & Homoya 2005; Swink & Wilhelm 1994). However, as Rothrock & Homoya (2005) have noted, the best quality reference sites in central Indiana have C_{av} ranging from 3.8-4.1. The C_{av} for the IMI site falls within this range. However, it was somewhat surprising that the C_{av} was not higher since 24 species (about 9.7% of the native species) had a coefficient of conservation of 8 or higher (Appendix 4). On the other hand, the site also contained an inordinate number of native plants with low C-values, that is, 120 species (about 48.8% of the native species) had a coefficient of conservation of 3 or lower. Rothrock & Homoya (2005) suggested that central Indiana natural areas have a limited number of species from the highest fidelity categories for unspecified “historical or innate biological reasons.” I would suggest that one important reason for the low number of these quality plants is due to the isolation of pristine or near-pristine habitats resulting from intense anthropogenic activities in the region, especially agriculture and urbanization.

The FQI and C_{av} for all species, both native and adventives, provide additional information about the flora at the IMI wetland complex. The FQI for all species is 57.3, or only 4.6 units lower than the FQI for native species alone. Likewise, for all species, including adventives, the C_{av} is 3.4, compared to a C_{av} of 3.9 for native species alone. Rothrock & Homoya (2005) have suggested that natural quality of an area is compromised when adventive diversity lowers C_{av} by more than 0.7 units. Based on the numbers for IMI, it appears that the exotics are having only a minimal negative impact on the native species. Of the 41 exotic species documented, only six actually occurred in the wetland habitats. Four were rare; only *Agrostis gigantea* was abundant (found in the wet meadow) and *Prunella vulgaris* was infrequent. The remaining 35 exotic species occurred in the dry woods and field along the western border of the site.

As a wetland complex containing fens in east-central Indiana, the IMI site should be rated as good to very good. In addition to a number of high-quality fen species, the site did contain two rare state listed species and three species on the state watch list. However, when compared to the remarkable Cabin Creek Raised Bog (fen) in Randolph

County, or to the high-quality fens found in the northern tier of counties in Indiana, the lower quality of the fens at IMI easily becomes apparent (Ruch et al. 2008b).

Fen Hydrology: Amon et al. (2002) define one characteristic of fens as a wetland with permanent soil saturation, although it is very rarely inundated. He also states that Midwestern fens are located in regions of discharging ground water. Both these statements accurately describe the slope fen and wetland complex on the IMI property. Additionally, Amon et al. (2002) suggests that a second important aspect of fen hydrology is a relatively constant water level, even during dry conditions. This was also characteristic of the IMI site, as the water levels remained fairly constant year-round. Throughout the growing season, the depth to free water averaged 12 cm.

Chemistry of the IMI Wetland Complex: The entire complex fits the chemical profile of the temperate Midwestern fen as described by Amon et al. (2002), Malterer et al. (1987), Mitsch and Gosselink (2000), Richardson & Vepraskas (2001), Shedlock et al. (1993), Stewart et al. (1993), and Wilcox et al. (1986) (Table 5). Electrical conductivity, measured in microsiemens, had a mean of 624 for other Midwestern fens and a value of 595 muS for the IMI fen. This mean value for the IMI fen is well within the standard error for Midwestern fens. The level of pH at IMI fen is actually higher than the average for other reported Midwestern fens, but the upper and lower reported values for the IMI fen were within the pH values reported for Midwestern fens.

Table 5. Summary of the chemistry of fens in the temperate Midwest. (From Amon et al. (2002), Malterer et al. (1987), Mitsch & Gosselink (2000), Richardson & Vepraskas (2001), Shedlock et al. (1993), Stewart et al. (1993), and Wilcox et al. (1986).)

Ground Water	Mean	Lower Range	Upper Range	Standard Error	n
Electrical Conductivity (muS)	624	146	1523	69	70
IMI	595	280	1536	16	143
pH	7.29	6.31	8.29	0.05	70
IMI	7.5	7	8.1	0.06	30
Calcium (mg/L)	101	50	292	15	76
IMI	78	49	122	3	30
Magnesium (mg/L)	34	9.7	88	5.5	76
IMI	21	14	31	0.9	30
Ca/Mg ratio	2.4				
IMI	3.71				
Ammonia (mg/L)	0.3	<.02	1.35	0.18	60
IMI	BD				
Iron (mg/L)	0.14	<0.1	598	0.36	70
IMI	0.7	<0.02	3.79	0.16	29
Sulfate (mg/L)	123	<1	870	43	44
IMI	12.7	3	22	0.8	30

The level of calcium at the IMI fen, 78 milligrams per liter, was lower than the average for Midwestern fens, 101 mg/L. However, the levels of calcium at the IMI fen were within the range of values for Midwestern fens. It should be noted that this is the level of calcium in the groundwater, not the level of calcium carbonate. The level of magnesium at IMI, 21 mg/L, was also lower than the average magnesium levels at Midwestern fens, 34 mg/L, but as with calcium, the ranges for the magnesium levels at the IMI fen fell within the reported values for magnesium levels for Midwestern fens. While the mean values for calcium and magnesium at the IMI fen were both lower than the mean levels reported at Midwestern fens, the ratio of calcium to magnesium at the IMI fen, 3.7 Ca/Mg, was higher than the ratio for Midwestern fens, 2.4 Ca/Mg. Ground water levels of ammonia at the IMI fen were below the detectable limit of 0.1 mg/L. The average for Midwestern fens was a low 0.3 mg/L, placing the IMI fen within the normal range. Iron levels at the IMI fen were higher than the reported values for Midwestern fens, but still are within the range for Iron levels at other Midwestern fens. The average values for both the IMI fen, 0.7 mg/L, and for Midwestern fens, 0.14 mg/L, are still less than 1 milligram per liter. The levels of Sulfate at Midwestern fens are one value that is almost an order of magnitude larger than the values at the IMI fen. The IMI fen had an average Sulfate level of 12.7 milligrams per liter, while the average Midwestern fen had 123 milligrams per liter of Sulfate in the ground water. This large value may possibly be due to extra large Sulfate values at some Midwestern fens and may be distorting the true mean. The IMI fen still falls within the range for Sulfate levels at Midwestern fens. Cation Exchange Capacity, consistently high at the IMI fen, falls into the expected range for soils with high organic content (Mengel 1980), indicating the soils large capacity to hold cations.

Water chemistry has limited utility in separating fens from their surroundings, particularly because both are influenced by the same water and geology (Amon et al. 2002). Bogs are very rare in the temperate Midwest, and most fens do not gradate from bog to fen as typically seen in the boreal zone (Mitch & Gosselink 2000). Typical fen to non-fen transitions are from fen to lake, fen to marsh, fen to shrub-carr, fen to wet prairie, or fen to sedge meadow (Amon et al. 2002). Portions of the IMI wetland complex had transitions from fen to shrub-carr and fen to mesic woodland.

Levels of calcium carbonate and pH, while descriptive of a fen, are not useful in distinguishing the boundaries of Midwestern fens because of the strong influence by soil parent material and glacial outwash material. Still, there is an effort to describe the chemistry of fen plant communities to understand the characteristics of fens in general. According to Amon et al. (2002), conductivity is the most consistent chemical parameter distinguishing fens from bogs. Conductivity at the IMI fen was consistently high, in the same range as reported by Amon et al. (2002). Bowles et al. (2005) suggests that percent base concentration has the most utility in determining patterns in fen vegetation. There are several other Midwestern fens that have similar chemistry as the IMI fen. Waters at Cowles Bog wetland complex in Porter County, Indiana, were dominated by calcium and magnesium bicarbonate, and by pH values in the circum-neutral range (Wilcox et al. 1986). Choesin & Boerner (2000) also found high alkalinity at Betsch Fen in southwestern Ohio, with values comparable to the IMI fen. Fens in northeastern Illinois had median alkalinity levels (mg $CaCO_3$ per liter) of 368, 408, and 310 and median pH values of 7.4, 7.5, and 7.2 (Panno et al. 1999).

In boreal zones, much research has been done to determine the chemical and physical parameters responsible for the distinction between the different vegetation communities of bogs and fens. The classical results are that fens are minerotrophic with waters rich in calcium and magnesium bicarbonates and circum-neutral pH values (Boelter & Verry 1977; Curtis 1959), and the vegetation gradient from bog to rich fen clearly is related to pH and calcium content of both peat and water (Persson 1962, Sjors 1952). In northwestern Europe the distinctions between rich and poor fens is surface water about 5.5 pH (Malmer 1986).

Correlation Between Fen Vegetation and Ground Water: Three studies have looked to correlate fen vegetation patterns with ground water chemistry. Holte (1966) could find no correlation between ground water chemistry and strong fen vegetation zonal patterns. In nine Alberta fens, Slack et al. (1980) found that water levels were more important to vegetation zonal patterns than ground water chemistry. Lastly, Carpenter (1995) found no plant community zonation patterns related to ground water chemistry in a study covering sixteen fens in Wisconsin. These studies differed from the IMI study by comparing plant communities or zones to ground water chemistry instead of searching for correlations between fen plant species and chemical and physical parameters using multivariate statistics. One study on a prairie fen in Illinois used multivariate analysis to correlate plant communities with environmental parameters (Bowles 2005). While it may be possible to infer plant species correlation with environmental parameters from their vegetative zones, the emphasis was on patterns of zonation within a fen.

LITERATURE CITED

Amon, J.P., C.A. Thompson, Q.J. Carpenter & J. Miner. 2002. Temperate zone fens of the glaciated Midwestern USA. Wetlands 22(2):301-317.

Boelter, D.H. & E.S. Verry. 1977. Peatland and water in the northern lake states. U.S.D.A. Forest General Technical Report NC-31. North Central Forest Experiment Station, St. Paul, Minnesota. 26 pp.

Bowles, M.L., P.D. Kelsey, & J.L. McBride. 2005. Relationships among environmental factors, vegetation zones, and species richness in a North American calcareous prairie fen. Wetlands 25(3):685-696.

Carpenter, Q.J. 1995. Toward a new definition of calcareous fen for Wisconsin (USA). Ph. D. Dissertation. Institute for Environmental Studies, University of Wisconsin, Madison, WI, USA.

Choesin, D.N. & R.E.J. Boerner. 2000. Vegetation and ground water alkalinity of Betsch Fen, a remnant periglacial fen in South Central Ohio. Castanea 65(3):193-206.

Cowardin, L.M., V. Carter, F.C. Golet & E.T. Laroe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish & Wildlife Service Pub. FWS/OBS-79/31, Washington, D.C. 103 pp.

Curtis, J.T. 1959. The Vegetation of Wisconsin. University of Wisconsin Press, Madison, WI, USA. 640 pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Scientist 33:43-64.

Doudna, J. 2008. Ecological application of ordination techniques in the literature. At http://userwww.sfsu.edu/~efc/classes/biol710/ordination/ordination-new.htm.

Gorham, E. 1991. Northern peatlands: role in the carbon cycle and probable response to climate warming. Ecological Applications 1:182-195.

Holte, K.E. 1966. A floristic and ecological analysis of the Excelsior Fen complex in northwest Iowa. Ph.D. Dissertation. University of Iowa, Iowa City, IA, USA. 292 pp.

IDNR (Indiana Department of Natural Resources), Division of Outdoor Recreation. 1989. Wetlands...Indiana's Endangered Natural Resource. Appendix to Indiana Outdoor Recreation 1989: An Assessment and Policy Plan. 23 pp.

Malmer, N. 1986. Vegetational gradients in relation to environmental conditions in northwestern European mires. Can. J. Bot. 64:375-383.

Malterer, T.J., A.J. Duxbury & J.L. Richardson. 1987. Soil characteristics of three calcareous fens in North Dakota and Minnesota. Proceedings North Dakota Academy of Science 41:65.

Mengel, D.B. 1980. Fundamentals of Soil Cation Exchange Capacity. Agronomy Guide AY-238, Purdue University Cooperative Extension Service, West Lafayette, IN 47907. At http://www.extension.purdue.edu/extmedia/AY/AY-238.html.

Mitsch, W.J. & J.G. Gosselink. 2000. Wetlands. John Wiley & Sons, New York, New York. 920 pp.

Panno, S.V., V.A. Nuzzo, K. Cartwright, B.R. Hensel & I.G. Krapac. 1999. Impact of urban development on the chemical composition of ground water in a fen-wetland complex. Wetlands 19:236-245.

Persson, A. 1962. Mire and spring vegetation in an area north of Lake Tornetrask, Torne Lappmark, Sweden, II. Habitat conditions. Opera Botanica 6(3):1-100.

Richardson, J. L. & M.J. Vepraskas. (eds.) 2001. Wetland Soils – Genesis, Hydrology, Landscapes and Classification. Lewis Publishers, Boca Raton, FL, USA. 417 pp.

Rothrock, P.E., H. Starcs, R. Dunbar & R.L. Hedge. 1993. The vascular flora of Mounds State Park, Madison County, Indiana. Proceedings of the Indiana Academy of Science 102:161-199.

Rothrock, P.E. 1997. The vascular flora of Fogwell Forest Nature Preserve, Allen County, Indiana. Proceedings of the Indiana Academy of Science 106:267-290.

Rothrock, P.E. 2004. Floristic quality assessment in Indiana: The concept, use and development of coefficients of conservatism. Final Report for ARN A305 4 53, EPA Wetland Program Development Grant CD975586 01. 96 p. At http://www.in.gov/idem/water/planbr/401/publications.html.

Rothrock, P.E. & M.A. Homoya. 2005. An evaluation of Indiana's floristic quality assessment. Proceedings of the Indiana Academy of Science 114(1):9-18.

Ruch, D.G., A. Schoultz & K.S. Badger. 1998. The flora and vegetation of Ginn Woods, Ball State University, Delaware County, Indiana. Proceedings of the Indiana Academy of Science 107:17-60.

Ruch, D.G., B.G. Torke, C.R. Reidy, K.S. Badger & P.E. Rothrock. 2002. The flora and vegetational communities of Wilbur Wright Fish and Wildlife Area, Henry County, Indiana. Proceedings of the Indiana Academy of Science 111:147-176.

Ruch, D.G., C.R. Reidy, B.G. Torke, K.S. Badger & P.E. Rothrock. 2004. Additions to the flora of Ginn Woods, Delaware County, Indiana. Proceedings of the Indiana Academy of Science 113:1-6.

Ruch, D.G., B.G. Torke, K.S. Badger, C.R. Reidy, P.E. Rothrock, R. Waltz, E.G. Urly, J.L. Chance & L. Click. 2007. The vascular flora and vegetational communities of Hayes Arboretum in Wayne County, Indiana. Proceedings of the Indiana Academy of Science 116:11-41.

Ruch, D.G., B.G. Torke, K.S. Badger, B.R. Hess, B.N. Christian & P.E. Rothrock. 2008a. The vascular flora and vegetational communities of Lick Creek Summit Nature Preserve in Wayne County, Indiana. Proceedings of the Indiana Academy of Science 117(1):29-54.

Ruch, D.G., B.G. Torke, B.R. Hess, K.S. Badger, and P.E. Rothrock. 2008b. The vascular flora and vegetational communities of the wetland complex on the IMI Property in Henry County near Luray, Indiana. Proceedings of the Indiana Academy of Science 117(2):142-158.

Shedlock, R. J., D.A. Wilcox, T.A. Thompson & D.A. Cohen. 1993. Interactions between ground water and wetlands, southern shore of Lake Michigan, USA. Journal of Hydrology 141:127-155.

Sjors, H. 1952. On the relation between vegetation and electrolytes in northern Swedish mire waters. Oikos, 2:241-258.

Slack, N.G., D.H. Vitt & D.G. Horton. 1980. Vegetation gradients of minerotrophically rich fens in western Alberta. Canadian Journal of Botany 58:330-350.

Stewart, P.M., K. Kessler & R. Dunbar. 1993. Intrafen and interfen variation of Indiana fens: water chemistry. Proceedings of the Indiana Academy of Science 102:207-217.

Stonehouse, A.L., K.S. Badger, D.G. Ruch & P.E. Rothrock. 2003. A floristic inventory and description of the structure and composition of the plant communities of Botany Glen, Grant County, Indiana. Proceedings of the Indiana Academy of

Science 112:135-159.

Swink, F. & G. Wilhelm. 1994. Plants of the Chicago Region. The Morton Arboretum, Lisle, Illinois. 932 pp.

The Nature Conservancy. 2002. Berkshire Taconic Landscapes: Sloping Fen. At http://www.lastgreatplaces.org/berkshire/wetlands/art6576.html.

U.S.D.A. 2008. Natural Resources Conservation Services Plants National Database. At http://plants.usda.gov/index.html.

Wilcox, D.A., R.J. Shedlock & W.H. Hendrickson. 1986. Hydrology, water chemistry, and ecological relations in the raised mound of Cowles Bog. Journal of Ecology 74:1103-1117.

Wilhelm, G. & L. Masters. 2000. Floristic Quality Assessment and Computer Applications. Conservation Research Institute, 324 N. York Street, Elmhurst, Illinois 60126.

Wisconsin Wetland Association. 2002. Wetlands of Wisconsin. At www.wiscwetlands.org/calcfens.htm.

Appendix I. Environmental Matrices.

Area	Sample	Surface Water Alkalinity, CaCO3 mg/L	Surface Water Conductivity mmho/cm	Surface Water pH	Surface Water Solids, Total_Dissolved (est.) mg/L	Surface Water Chloride mg/L	Surface Water Nitrogen, Ammonia (as_N) mg/L	Surface Water Nitrogen, Nitrate+Nitrite (as_N) mg/L	Surface Water Phosphorus, Ortho (as_P) mg/L	Surface Water Carbonate (CO3) mg/L	Surface Water Bicarbonate (HCO3) mg/L	Surface Water Calcium mg/L	Surface Water Iron mg/L
1	June	314	0.59	7.65	378	4.42	3.79	0.64	BDL	BDL	381	88.0	1.01
	Aug	245	0.49	7.60	311	5.68	BDL	BDL	BDL	BDL	297	72.9	0.62
	Sept	229	0.48	7.75	305	6.47	BDL	BDL	BDL	1.0	277	66.6	0.13
2	June	303	0.58	7.65	368	3.48	0.99	0.43	0.15	1.0	368	77.4	0.14
	Aug	2648	0.51	7.35	327	5.96	1.01	0.33	BDL	3.0	3225	84.5	0.43
	Sept	1036	0.58	7.40	370	5.17	0.84	0.28	BDL	6.0	1256	103.9	2.82
3	June	1380	0.54	7.40	347	4.09	1.14	BDL	BDL	8.7	1669	79.0	0.89
	Aug	4122	0.49	7.28	314	7.08	0.70	BDL	0.13	5.3	5018	83.3	1.17
	Sept	877	0.57	7.25	360	5.06	0.78	BDL	BDL	2.7	1065	79.9	0.33
4	June	170	0.40	7.90	253	4.56	BDL	0.53	BDL	1.0	205	56.7	0.15
	Aug	2001	0.46	7.65	291	4.89	0.33	BDL	BDL	4.0	2435	68.6	0.44
	Sept	1096	0.43	7.75	275	4.70	BDL	BDL	BDL	9.0	1327	59.2	0.70
							DL = 0.10 mg/L	DL = 0.20 mg/L	DL = 0.10 mg/L	DL = 1 mg/L			DL = 0.02 mg/L

Area	Sample	Surface Water Potassium mg/L	Surface Water Magnesium mg/L	Surface Water Manganese mg/L	Surface Water Sodium mg/L	Surface Water Sulfur (as_Sulfate) mg/L	Surface Water Sodium_Absorption_Ratio(SAR)	Surface Water BOD, 5-Day mg/L	Monitoring Well pH	Monitoring Well Conductivity	Monitoring Well Alkalinity	Soil Organic Matter %	Soil Phosphorus, Bray P1 ppm-P
1	June	1.70	20.6	0.72	2.80	9.0	0.1	6.0	7.33	683.00	381.76	16.3	7.5
	Aug	1.85	19.2	0.24	3.65	17.5	0.1	18.5	7.34	761.61	514.86		
	Sept	1.00	18.0	BDL	2.55	17.0	0.1	4.0	7.46	541.65	393.96	14.4	1.0
2	June	1.20	27.6	BDL	2.05	11.0	0.1	4.0	7.41	662.88	423.55	24.0	8.5
	Aug	1.30	25.9	0.12	2.40	12.5	0.1	73.0	7.14	669.13	449.94		
	Sept	2.00	26.7	1.02	2.15	17.0	BDL	32.0	7.46	579.14	390.84	10.6	3.5
3	June	1.37	21.5	0.99	2.25	11.3	0.1	51.0	7.44	493.25	280.23	15.5	5.0
	Aug	1.53	21.7	0.39	2.63	11.5	0.1	202.8	7.29	474.94	287.12	20.4	6.0
	Sept	1.57	22.4	0.08	2.53	11.0	0.1	61.3	7.52	451.57	284.70	18.3	4.5
4	June	1.00	15.3	BDL	2.05	16.0	0.1	BDL	7.55	592.00	335.69	17.5	4.5
	Aug	BDL	16.4	0.39	2.90	12.5	0.1	20.0	7.30	665.57	460.41	14.8	1.5
	Sept	1.30	15.6	BDL	2.30	10.5	0.1	26.0	7.66	631.75	434.61	15.5	2.0
		DL = 1.0 mg/L		DL = 0.04 mg/L			DL = 0.1	DL = 1 mg/L					

Area	Sample	Soil Potassium K ppm	Soil Magnesium Mg ppm	Soil Calcium Ca ppm	Soil Sodium Na ppm	Soil pH	Soil Cation Exchange Capacity meq/100g	Soil Sulfer S ppm	Soil Zinc Zn ppm
1	June	41.0	448	19150	23.5	7.85	87.85	61.00	4.10
	Aug								
	Sept	39.0	368	26875	11.0	7.90	99.90	31.50	3.95
2	June	31.0	510	6225	20.0	7.70	35.55	79.00	3.90
	Aug								
	Sept	58.0	563	16525	11.5	7.70	63.65	16.00	4.15
3	June	25.3	490	18367	19.7	8.03	88.13	32.33	3.17
	Aug	7.7	248	7983	9.0	7.97	42.07	11.00	2.43
	Sept	44.3	463	12188	13.8	7.73	61.55	23.50	4.53
4	June	15.0	345	14325	15.0	8.20	74.60	22.00	3.05
	Aug	16.0	440	19475	14.5	8.00	95.10	28.50	2.85
	Sept	31.0	433	18650	14.0	7.95	84.75	28.00	4.90

Area	Sample	Soil Manganese Mn ppm	Soil Iron Fe ppm	Soil Copper Cu ppm	Soil Boron B ppm	Soil Soluble Salts mmhos/cm	Soil Percent Base Saturation, K	Soil Percent Base Saturation, Mg	Soil Percent Base Saturation, Ca	Soil Percent Base Saturation, Na
1	June	29.00	19.50	1.30	1.40	0.35	0.2	4.1	95.7	0.1
	Aug									
	Sept	16.50	1.00	0.85	1.00	0.15	0.1	2.3	97.7	0.0
2	June	24.00	86.50	0.85	2.10	0.40	0.2	13.0	86.5	0.2
	Aug									
	Sept	25.50	15.50	1.20	1.75	0.10	0.4	8.7	90.8	0.1
3	June	30.00	21.67	0.73	1.33	0.23	1.3	35.3	63.3	0.1
	Aug	22.33	68.67	0.63	1.13	0.17	0.1	6.5	93.3	0.2
	Sept	35.50	44.25	1.35	1.75	0.18	0.3	8.2	91.5	0.1
4	June	38.50	23.50	0.80	1.05	0.15	0.1	4.0	96.0	0.1
	Aug	24.00	13.00	0.75	1.20	0.20	0.0	3.6	96.3	0.1
	Sept	24.00	15.00	1.00	1.25	0.20	0.1	3.8	96.0	0.1

Appendix 2. Species Matrices (Floristic Quality Assessment).

	POLYGON 1			
Species	**IV1**	**IV2**	**IV3**	**AVE**
Carex stricta	12.98	10.41	8.71	10.70
Carex sterilis	9.28	5.65	4.89	6.61
Dasiphora fruticosa	7.63	5.87	4.67	6.06
Solidago patula	5.06	6.03	4.99	5.36
Rudbeckia fulgida	6.90	5.01	3.78	5.23
Packera aurea	6.10	4.63	4.80	5.18
Impatiens capensis	5.34	3.63	3.12	4.03
Pycnanthemum virginianum	4.64	3.30	3.78	3.91
Symphyotrichum puniceum	4.64	4.16	2.79	3.86
Equisetum arvense	5.08	2.22	2.50	3.27
Lysimachia quadriflora	0.00	4.74	3.08	2.61
Iris virginica	3.24	2.43	1.62	2.43
Equisetum hyemale	2.48	2.22	2.26	2.32
Eupatoriadelphus maculatus	0.00	3.63	3.12	2.25
Oxypolis rigidior	2.96	1.86	1.62	2.15
Viola cuculata	2.96	1.50	1.91	2.12
Elaeagnus umbellata	3.53	1.50	1.33	2.12
Pedicularis lanceolata	2.00	2.43	1.91	2.12
Galium asprellum	2.48	1.86	1.33	1.89
Carex leptalea	3.53	0.00	1.62	1.72
Scirpus atrovirens	2.00	1.50	1.62	1.71
Galium triflorum	0.00	2.22	2.20	1.47
Eleocharis elliptica	0.00	1.86	2.50	1.45
Pilea fontana	0.00	1.86	2.50	1.45
Carex buxbaumii	4.21	0.00	0.00	1.40
Lycopus uniflorus	0.00	1.86	1.91	1.26
Eleocharis sp.	0.00	1.86	1.62	1.16
Parthenocissus quinquefolia	0.00	1.86	1.62	1.16
Lycopus americanus	0.00	1.86	1.33	1.06
Muhlenbergia frondosa	0.00	1.50	1.62	1.04
Oligoneuron riddellii	0.00	1.50	1.62	1.04
Solidago uliginosa	0.00	0.00	3.08	1.03
Cardamine bulbosa	2.96	0.00	0.00	0.99
Agrostis gigantea	0.00	1.50	1.33	0.94
Apocynum cannabinum	0.00	1.50	1.33	0.94
Carex cryptolepis	0.00	1.50	1.33	0.94
Eupatorium perfoliatum	0.00	1.50	1.33	0.94
Leersia oryzoides	0.00	1.50	1.33	0.94
Prunella vulgaris	0.00	1.50	1.33	0.94
Agalinis purpurea	0.00	0.00	1.33	0.44
Juncus brachycephalus	0.00	0.00	1.33	0.44
Salix petiolaris	0.00	0.00	1.33	0.44
Schizachyrium scoparium	0.00	0.00	1.33	0.44
Sorghastrum nutans	0.00	0.00	1.33	0.44
	100.00	100.00	100.00	100.00

POLYGON 2

Species	IV1	IV2	IV3	AVE
Carex stricta	12.23	12.49	11.78	12.17
Pycnanthemum virginianum	6.72	7.33	6.84	6.96
Symphyotrichum puniceum	6.63	4.54	4.06	5.07
Dasiphora fruticosa	4.79	6.15	3.17	4.71
Oxypolis rigidior	5.02	4.92	2.70	4.21
Eleocharis elliptica	3.54	4.54	3.72	3.93
Packera aurea	4.05	3.79	3.72	3.85
Equisetum arvense	5.02	3.04	2.02	3.36
Solidago patula	3.08	3.04	3.52	3.21
Thelypteris palustris	2.31	3.79	3.04	3.04
Cornus amomum	2.50	2.49	2.70	2.56
Lycopus americanus	2.31	2.28	2.02	2.20
Toxicodendron radicans	1.92	2.66	2.02	2.20
Lysimachia quadriflora	0.00	3.41	3.04	2.15
Filipendula rubra	3.07	1.53	1.68	2.09
Viola cuculata	2.31	1.91	2.02	2.08
Ulmus americana	1.92	1.53	2.17	1.88
Unknown grass	1.92	2.28	1.34	1.85
Vitis riparia	1.92	1.91	1.68	1.84
Carex sterilis	3.56	0.00	1.68	1.75
Impatiens capensis	1.92	1.91	1.34	1.72
Selaginella apoda	1.92	1.53	1.34	1.60
Rosa setigera	1.54	1.53	1.68	1.58
Elaeagnus umbellata	1.54	1.53	1.34	1.47
Galium triflorum	1.54	1.53	1.34	1.47
Rosa multiflora	1.54	1.53	1.34	1.47
Lycopus uniflorus	0.00	2.28	2.02	1.43
Rudbeckia hirta	2.50	1.53	0.00	1.34
Salix discolor	0.00	0.00	3.33	1.11
Eupatoriadelphus maculatus	0.00	1.91	1.34	1.08
Rudbeckia fulgida	0.00	1.53	1.68	1.07
Carex tetanica	3.09	0.00	0.00	1.03
Unknown opp lv plant	1.54	0.00	1.34	0.96
Asclepias incarnata	0	1.53	1.34	0.96
Leersia oryzoides	0.00	1.53	1.34	0.96
Solidago canadensis	0.00	1.53	1.34	0.96
Agrostis gigantea	0	0.00	2.70	0.90
Carex leptalea	2.68	0.00	0.00	0.89
Carex pellita	1.92	0.00	0.00	0.64
Glyceria striata var. stricta	1.92	0.00	0.00	0.64
Cercis canadensis	0.00	1.91	0.00	0.64
Agalinis purpurea	0	0.00	1.68	0.56
Muhlenbergia frondosa	0.00	0.00	1.68	0.56
Unknown basal leaves	0.00	0.00	1.68	0.56
Cardamine bulbosa	1.54	0.00	0.00	0.51
Acer saccharum	0	1.53	0	0.51
Eleocharis erythropoda	0.00	1.53	0.00	0.51

Muhlenbergia glomerata	0.00	0.00	1.34	0.45
Oligoneuron riddellii	0.00	0.00	1.34	0.45
Solidago uliginosa	0.00	0.00	1.34	0.45
Sorghastrum nutans	0.00	0.00	1.34	0.45
	100.00	100.00	100.00	100.00

POLYGON 3

Species	**IV1**	**IV2**	**IV3**	**AVE**
Carex stricta	16.20	15.13	13.90	15.08
Impatiens capensis	13.61	11.93	10.40	11.98
Symphyotrichum puniceum	8.64	6.95	6.66	7.41
Thelypteris palustris	6.91	7.16	6.56	6.88
Pilea fontana	4.35	6.04	6.72	5.70
Solidago patula	5.05	5.42	6.10	5.52
Salix petiolaris	3.69	4.17	4.66	4.17
Leersia oryzoides	1.50	5.21	5.54	4.08
Symplocarpus foetidus	9.09	2.06	0.00	3.72
Eupatoriadelphus maculatus	2.09	3.88	3.86	3.28
Cuscuta gronovii	0.00	3.86	4.35	2.73
Eupatorium perfoliatum	1.77	3.29	2.88	2.65
Filipendula rubra	2.63	1.92	1.45	2.00
Pycnanthemum virginianum	1.69	1.65	2.08	1.81
Glyceria striata	3.57	1.28	0.00	1.62
Cardamine bulbosa	3.47	1.05	0.00	1.51
Carex hystericina	1.98	1.28	1.22	1.49
Typha latifolia	1.17	3.06	0.00	1.41
Packera aurea	1.69	1.13	1.24	1.36
Equisetum arvense	1.43	1.13	1.03	1.20
Lycopus uniflorus	0.00	1.13	2.25	1.13
Galium triflorum	1.17	1.13	1.03	1.11
Oxypolis rigidior	1.17	1.13	1.03	1.11
Rosa setigera	1.17	1.13	1.03	1.11
Viola cuculata	1.23	1.05	1.03	1.11
Vitis riparia	0.00	1.05	2.25	1.10
Rumex obtusifolius	0.00	2.19	1.03	1.07
Solanum dulcamara	0.00	1.28	1.43	0.90
Lycopus americanus	1.23	1.13	0.00	0.79
Ulmus americana	1.17	1.13	0.00	0.77
Viburnum lentago	1.17	0.00	1.03	0.73
Carex lurida	0.00	0.00	1.43	0.48
Muhlenbergia frondosa	0.00	0.00	1.24	0.41
Epilobium coloratum	0.00	0.00	1.22	0.41
Polygonum punctatum	0.00	0.00	1.22	0.41
Carex pellita	1.17	0.00	0.00	0.39
Acer saccharum	0.00	0.00	1.03	0.34

Fraxinus pennsylvanica	0.00	0.00	1.03	0.34
Parthenocissus quinquefolia	0.00	0.00	1.03	0.34
Rosa multiflora	0.00	0.00	1.03	0.34
	100.00	100.00	100.00	100.00

POLYGON 4

Species	**IV1**	**IV2**	**IV3**	**AVE**
Carex stricta	28.03	23.19	25.02	25.41
Impatiens capensis	11.78	10.12	11.32	11.08
Symphyotrichum puniceum	12.00	11.69	9.15	10.95
Solidago patula	8.41	5.29	7.42	7.04
Eupatoriadelphus maculatus	3.27	8.15	6.54	5.99
Leersia oryzoides	0.00	5.90	7.46	4.45
Pycnanthemum virginianum	4.01	4.82	3.62	4.15
Thelypteris palustris	4.74	4.07	3.62	4.15
Chelone glabra	5.81	2.85	2.99	3.88
Eupatorium perfoliatum	0.00	5.57	5.47	3.68
Glyceria striata	6.75	4.07	0.00	3.61
Cuscuta gronovii	0.00	2.85	4.80	2.55
Carex pellita	3.27	2.85	0.00	2.04
Cardamine bulbosa	6.11	0.00	0.00	2.04
Equisetum hyemale	0.00	2.85	2.99	1.95
Solanum nigrum	0.00	2.85	2.99	1.95
Filipendula rubra	5.81	0.00	0.00	1.94
Lycopus uniflorus	0.00	0.00	3.62	1.21
Scirpus atrovirens	0.00	0.00	2.99	1.00
Carex hystericina	0.00	2.85	0.00	0.95
	100.00	100.00	100.00	100.00

Appendix 3. Plant Inventory at the IMI Wetland Complex.

Genus	Species	Family	Common name
Acer	*negundo*	Aceraceae	Boxelder
Acer	*saccharum*	Aceraceae	Sugar maple
Achillea	*millefolium*	Asteraceae	Common yarrow
Agalinis	*purpurea*	Scrophulariaceae	Smooth agalinis
Ageratina	*altissima*	Asteraceae	White snakeroot
Agrimonia	*parviflora*	Rosaceae	Swamp agrimony
Agrimonia	*pubescens*	Rosaceae	Downy agrimony
Agrostis	*gigantea*	Poaceae	Redtop
Ailanthus	*altissima*	Simaroubaceae	Tree-of-Heaven
Alliaria	*petiolata*	Brassicaceae	Garlic mustard
Allium	*burdickii*	Liliaceae	Ramps
Allium	*canadense*	Liliaceae	Wild garlic
Ambrosia	*artemisiifolia*	Asteraceae	Common ragweed
Ambrosia	*trifida*	Asteraceae	Great ragweed
Andropogon	*gerardii*	Poaceae	Big bluestem
Anemone	*virginiana*	Ranunculaceae	Thimbleweed
Apios	*americana*	Fabaceae	Common ground-nut
Apocynum	*cannabinum*	Apocynaceae	American Indian hemp
Arisaema	*dracontium*	Araceae	Green dragon
Arisaema	*triphyllum*	Araceae	Jack-in-the-pulpit
Asclepias	*incarnata*	Asclepiadaceae	Swamp milkweed
Asclepias	*syriaca*	Asclepiadaceae	Common milkweed
Asplenium	*platyneuron*	Aspleniaceae	Ebony spleenwort
Aureolaria	*virginica*	Scrophulariaceae	Downy false-foxglove
Barbarea	*vulgaris*	Brassicaceae	Bitter wintercress, Yellow rocket
Betula	*nigra*	Betulaceae	River birch
Bidens	*coronata*	Asteraceae	Northern tickseed sunflower
Blephilia	*hirsuta*	Lamiaceae	Hairy wood-mint
Botrychium	*dissectum*	Ophioglossaceae	Lace-frond grape fern
Botrychium	*virginianum*	Ophioglossaceae	Rattlesnake fern
Bromus	*arvensis*	Poaceae	Field (Japanese) brome
Bromus	*inermis*	Poaceae	Smooth brome
Caltha	*palustris*	Ranunculaceae	Marsh marigold
Calystegia	*sepium*	Convolvulaceae	Typical hedge-bindweed
Campanulastrum	*americanum*	Campanulaceae	Tall bellflower
Cardamine	*bulbosa*	Brassicaceae	Spring-cress
Cardamine	*concatenata*	Brassicaceae	Cut-leaved toothwort
Carex	*aggregata*	Cyperaceae	Glomerate sedge
Carex	*albursina*	Cyperaceae	White bear sedge
Carex	*blanda*	Cyperaceae	Eastern woodland sedge
Carex	*buxbaumii*	Cyperaceae	Dark-scaled sedge
Carex	*cryptolepis*	Cyperaceae	Small yellow sedge
Carex	*frankii*	Cyperaceae	Bristly cat-tail sedge
Carex	*granularis*	Cyperaceae	Pale sedge
Carex	*grisea*	Cyperaceae	Wood gray sedge

Carex	*hystericina*	Cyperaceae	Porcupine sedge
Carex	*laevivaginata*	Cyperaceae	Smooth-sheathed fox sedge
Carex	*leptalea*	Cyperaceae	Slender sedge
Carex	*lurida*	Cyperaceae	Bottle-brush sedge
Carex	*pellita*	Cyperaceae	Woolly sedge
Carex	*rosea*	Cyperaceae	Rosy sedge
Carex	*shortiana*	Cyperaceae	Short's sedge
Carex	*sterilis*	Cyperaceae	Fen star sedge
Carex	*stipata*	Cyperaceae	Common fox sedge
Carex	*stricta*	Cyperaceae	Common tussock sedge
Carex	*tetanica*	Cyperaceae	Rigid sedge
Carex	*vulpinoidea*	Cyperaceae	Brown fox sedge
Carpinus	*caroliniana*	Betulaceae	Hornbeam
Carya	*cordiformis*	Juglandaceae	Bitternut hickory
Carya	*ovata*	Juglandaceae	Shagbark hickory
Celastrus	*scandens*	Celastraceae	Bittersweet
Celtis	*occidentalis*	Ulmaceae	Hackberry
Cercis	*canadensis*	Fabaceae	Redbud
Chelone	*glabra*	Scrophulariaceae	White turtlehead
Cichorium	*intybus*	Asteraceae	Chicory
Cinna	*arundinacea*	Poaceae	Common woodreed
Circaea	*lutetiana*	Onagraceae	Common enchanter's nightshade
Cirsium	*arvense*	Asteraceae	Canada thistle
Cirsium	*discolor*	Asteraceae	Field thistle
Claytonia	*virginica*	Portulacaceae	Spring beauty
Commelina	*communis*	Commelinaceae	Common day-flower
Cornus	*drummondii*	Cornaceae	Rough-leafed dogwood
Cornus	*obliqua*	Cornaceae	Silky dogwood
Cornus	*racemosa*	Cornaceae	Northern swamp dogwood
Crataegus	*mollis*	Rosaceae	Downy hawthorn
Crataegus	*punctata*	Rosaceae	Dotted hawthorn
Cryptotaenia	*canadensis*	Apiaceae	Honewort
Cuscuta	*gronovii*	Cuscutaceae	Common dodder
Cyperus	*strigosus*	Cyperaceae	Straw-colored nutsedge
Dactylis	*glomerata*	Poaceae	Orchard grass
Dasiphora	*fruticosa*	Rosaceae	Shrubby cinquefoil
Daucus	*carota*	Apiaceae	Queen Anne's lace, Wild carrot
Desmodium	*canadense*	Fabaceae	Canada tick-trefoil
Desmodium	*canescens*	Fabaceae	Hoary Tick-trefoil
Dichanthelium	*acuminatum*	Poaceae	Western panic grass
Dioscorea	*villosa*	Dioscoreaceae	Wild yamroot
Dipsacus	*fullonum*	Dipsacaceae	Common teasel
Echinochloa	*muricata*	Poaceae	Rough barnyard grass
Elaeagnus	*umbellata*	Elaeagnaceae	Autumn olive
Eleocharis	*elliptica*	Cyperaceae	Elliptic spike rush
Eleocharis	*erythropoda*	Cyperaceae	Creeping spike rush
Elymus	*repens*	Poaceae	Quack grass
Elymus	*riparius*	Poaceae	Streambank wild rye
Elymus	*villosus*	Poaceae	Hairy wild rye

Elymus	*virginicus*	Poaceae	Virginia wild rye
Epilobium	*coloratum*	Onagraceae	Purple-leaf Willow-herb
Equisetum	*arvense*	Equisetaceae	Field horsetail
Equisetum	*hyemale*	Equisetaceae	Common scouring rush
Erigeron	*annuus*	Asteraceae	Daisy fleabane
Erigeron	*philadelphicus*	Asteraceae	Philadelphia daisy
Erysimum	*cheiranthoides*	Brassicaceae	Wormseed mustard
Eupatoriadelphus	*maculatus*	Asteraceae	Spotted Joe-Pye-weed
Eupatorium	*perfoliatum*	Asteraceae	Boneset
Eupatorium	*serotinum*	Asteraceae	Late boneset
Festuca	*subverticillata*	Poaceae	Nodding fescue
Filipendula	*rubra*	Rosaceae	Queen of the prairie
Floerkea	*proserpinacoides*	Limnanthaceae	False mermaid
Fragaria	*virginiana*	Rosaceae	Thick-leaved wild strawberry
Fraxinus	*americana*	Oleaceae	White ash
Fraxinus	*Pennsylvanica p.*	Oleaceae	Red ash
Fraxinus	*Pennsylvanica s.*	Oleaceae	Green ash
Galium	*aparine*	Rubiaceae	Cleavers
Galium	*asprellum*	Rubiaceae	Rough bedstraw
Galium	*circaezans*	Rubiaceae	Wild licorice
Galium	*concinnum*	Rubiaceae	Shining bedstraw
Galium	*triflorum*	Rubiaceae	Sweet-scented bedstraw
Geum	*canadense*	Rosaceae	White avens
Geum	*vernum*	Rosaceae	Spring avens
Glechoma	*hederacea*	Lamiaceae	Gill-over-the-ground
Glyceria	*striata*	Poaceae	Fowl-mannagrass
Hackelia	*virginiana*	Boraginaceae	Stickseed
Helianthus	*grosseserratus*	Asteraceae	Sawtooth sunflower
Heliopsis	*helianthoides*	Asteraceae	False sunflower
Heuchera	*americana*	Saxifragaceae	Common alumroot
Humulus	*lupulus*	Cannabaceae	American hops
Hydrastis	*canadensis*	Ranunculaceae	Goldenseal
Hypericum	*perforatum*	Clusiaceae	Common St. John’s-wort
Hypericum	*punctatum*	Clusiaceae	Spotted St. John's-wort
Impatiens	*capensis*	Balsaminaceae	Orange jewelweed
Impatiens	*pallida*	Balsaminaceae	Yellow touch-me-not
Iris	*virginica*	Iridaceae	Southern blue flag
Juglans	*nigra*	Juglandaceae	Black walnut
Juncus	*brachycephalus*	Juncaceae	Small-headed rush
Juncus	*dudleyi*	Juncaceae	Dudley's rush
Juniperus	*virginiana*	Cupressaceae	Eastern red cedar
Lactuca	*biennis*	Asteraceae	Tall blue lettuce
Lactuca	*canadensis*	Asteraceae	Wild lettuce
Lactuca	*floridana*	Asteraceae	Blue lettuce
Laportea	*canadensis*	Urticaceae	Wood nettle
Leersia	*oryzoides*	Poaceae	Rice cut-grass
Leersia	*virginica*	Poaceae	White grass
Ligustrum	*obtusifolium*	Oleaceae	Privet
Lilium	*michiganense*	Liliaceae	Michigan lily

Lindera	*benzoin*	Lauraceae	Northern spicebush
Lobelia	*inflata*	Campanulaceae	Indian tobacco
Lobelia	*kalmii*	Campanulaceae	Brook lobelia
Lobelia	*siphilitica*	Campanulaceae	Great blue lobelia
Lonicera	*maackii*	Caprifoliaceae	Amur honeysuckle
Lonicera	*tatarica*	Caprifoliaceae	Tartarian honeysuckle
Lycopus	*americanus*	Lamiaceae	American water-horehound
Lycopus	*uniflorus*	Lamiaceae	Northern water-horehound
Lysimachia	*quadriflora*	Primulaceae	Smooth loosestrife
Lythrum	*alatum*	Lythraceae	Winged lythrum
Malus	*coronaria*	Rosaceae	Sweet crabapple
Medicago	*lupulina*	Fabaceae	Black medic
Medicago	*sativa*	Fabaceae	Alfalfa
Menispermum	*canadense*	Menispermaceae	Moonseed
Mimulus	*ringens*	Scrophulariaceae	Square-stemmed monkey-flower
Monarda	*fistulosa*	Lamiaceae	Wild bergamot
Morus	*alba*	Moraceae	White mulberry
Muhlenbergii	*frondosa*	Poaceae	Wirestem muhly
Muhlenbergii	*glomerata*	Poaceae	Marsh muhly
Muhlenbergii	*mexicana*	Poaceae	Satin grass
Oligoneuron	*riddellii*	Asteraceae	Riddell's goldenrod
Osmorhiza	*longistylis*	Apiaceae	Aniseroot
Oxalis	*stricta*	Oxalidaceae	Common yellow wood sorrel
Oxypolis	*rigidior*	Apiaceae	Common water-dropwort
Packera	*aurea*	Asteraceae	Heart-leaved groundsel
Parnassia	*glauca*	Saxifragaceae	American grass-of-parnassus
Parthenocissus	*quinquefolia*	Vitaceae	Virginia creeper
Parthenocissus	*vitacea*	Vitaceae	Grape woodbine
Pedicularis	*lanceolata*	Scrophulariaceae	Swamp-lousewort
Phleum	*pratense*	Poaceae	Timothy
Phlox	*maculata*	Polemoniaceae	Wild sweet-william
Phryma	*leptostachya*	Phrymaceae	Lopseed
Physalis	*heterophylla*	Solanaceae	Clammy ground cherry
Phytolacca	*americana*	Phytolaccaceae	Pokeweed
Pilea	*fontana*	Urticaceae	Lesser clearweed
Pilea	*pumila*	Urticaceae	Clearweed
Plantago	*rugelii*	Plantaginaceae	Red-stalked plantain
Platanus	*occidentalis*	Platanaceae	American sycamore
Poa	*compressa*	Poaceae	Canada bluegrass
Poa	*pratensis*	Poaceae	Kentucky bluegrass
Poa	*trivialis*	Poaceae	Rough bluegrass
Podophyllum	*peltatum*	Berberidaceae	Mayapple
Polemonium	*reptans*	Polemoniaceae	Spreading Jacob's ladder
Polygonatum	*biflorum*	Liliaceae	Smooth Solomon's seal
Polygonum	*aviculare*	Polygonaceae	Doorweed
Polygonum	*caespitosum*	Polygonaceae	Oriental lady's thumb
Polygonum	*punctatum*	Polygonaceae	Dotted smartweed
Polygonum	*scandens*	Polygonaceae	Climbing false buckwheat
Polygonum	*virginianum*	Polygonaceae	Woodland knotweed

Populus	*deltoides*	Salicaceae	Eastern cottonwood
Prunella	*vulgaris*	Lamiaceae	Selfheal
Prunus	*serotina*	Rosaceae	Black cherry
Pycnanthemum	*virginianum*	Lamiaceae	Virginia mountain-mint
Quercus	*macrocarpa*	Fagaceae	Burr oak
Quercus	*muhlenbergii*	Fagaceae	Chinquapin oak
Ranunculus	*abortivus*	Ranunculaceae	Small-flowered crowfoot
Ranunculus	*hispidus*	Ranunculaceae	Northern swamp buttercup
Ranunculus	*recurvatus*	Ranunculaceae	Hooked crowfoot
Rhamnus	*lanceolata*	Rhamnaceae	Lance-leaved buckthorn
Rhynchospora	*capillacea*	Cyperaceae	Needle beak-rush
Ribes	*cynosbati*	Grossulariaceae	Prickly gooseberry
Rosa	*multiflora*	Rosaceae	Multiflora rose
Rosa	*palustris*	Rosaceae	Swamp rose
Rosa	*setigera*	Rosaceae	Prairie rose
Rosa	*virginiana*	Rosaceae	Virginia rose
Rubus	*allegheniensis*	Rosaceae	Blackberry
Rubus	*occidentalis*	Rosaceae	Black raspberry
Rudbeckia	*fulgida*	Asteraceae	Eastern coneflower
Rudbeckia	*hirta*	Asteraceae	Black-eyed-Susan
Rumex	*crispus*	Polygonaceae	Curly dock
Rumex	*obtusifolius*	Polygonaceae	Bitter dock
Rumex	*orbiculatus*	Polygonaceae	Great water-dock
Sagittaria	*latifolia*	Alismataceae	Broadleaf arrowhead
Salix	*discolor*	Salicaceae	Pussy-willow
Salix	*eriocephala*	Salicaceae	Diamond willow
Salix	*Nigra*	Salicaceae	Black willow
Salix	*petiolaris*	Salicaceae	Meadow willow
Sambucus	*nigra*	Caprifoliaceae	Common elderberry
Sanguinaria	*canadensis*	Papaveraceae	Bloodroot
Sanicula	*canadensis*	Apiaceae	Canada black-snakeroot
Sanicula	*odorata*	Apiaceae	Clustered black-snakeroot
Sassafras	*albidum*	Lauraceae	Sassafras
Schedonorus	*phoenix*	Poaceae	Tall fescue
Schizachyrium	*scoparium*	Poaceae	Little bluestem
Scirpus	*atrovirens*	Cyperaceae	Black bulrush
Scirpus	*hattorianus*	Cyperaceae	Early dark-green bulrush
Scirpus	*pendulus*	Cyperaceae	Drooping bulrush
Selaginella	*apoda*	Selaginellaceae	Meadow spikemoss
Setaria	*faberi*	Poaceae	Nodding foxtail
Silene	*virginica*	Caryophyllaceae	Fire pink
Sisyrinchium	*angustifolium*	Iridaceae	Stout blue-eyed grass
Smilax	*ecirrhata*	Smilacaceae	Upright carrion flower
Smilax	*lasioneura*	Smilacaceae	Common carrion flower
Smilax	*tamnoides*	Smilacaceae	Bristly-greenbrier
Solanum	*dulcamara*	Solanaceae	Bittersweet nightshade
Solanum	*ptycanthum*	Solanaceae	Black nightshade
Solidago	*canadensis*	Asteraceae	Canada goldenrod
Solidago	*patula*	Asteraceae	Rough-leaved goldenrod

Solidago	*uliginosa*	Asteraceae	Northern bog goldenrod
Sorghastrum	*nutans*	Poaceae	Indian grass
Sphenopholis	*intermedia*	Poaceae	Slender wedge grass
Spiranthes	*lucida*	Orchidaceae	Shining ladies' tresses
Stellaria	*media*	Caryophyllaceae	Common chickweed
Symphyotrichum	*cordifolium*	Asteraceae	Common blue heart-leaved aster
Symphyotrichum	*dumosum*	Asteraceae	Long-stalked aster
Symphyotrichum	*firmum*	Asteraceae	Shining aster
Symphyotrichum	*lanceolatum*	Asteraceae	Eastern lined aster
Symphyotrichum	*lateriflorum*	Asteraceae	Calico aster
Symphyotrichum	*novae-angliae*	Asteraceae	New England aster
Symphyotrichum	*pilosum*	Asteraceae	Frost aster
Symphyotrichum	*puniceum*	Asteraceae	Bristly aster
Symplocarpus	*foetidus*	Araceae	Skunk-cabbage
Taraxacum	*officinale*	Asteraceae	Dandelion
Taxodium	*distichum*	Taxodiaceae	Bald cypress
Teucrium	*canadense*	Lamiaceae	American germander
Thaspium	*trifoliatum*	Apiaceae	Meadow-parsnip
Thelypteris	*palustris*	Thelypteridaceae	Marsh fern
Tilia	*americana*	Tiliaceae	Basswood
Toxicodendron	*radicans*	Anacardiaceae	Common poison-ivy
Toxicodendron	*rydbergii*	Anacardiaceae	Western poison-ivy
Trifolium	*pratense*	Fabaceae	Red clover
Trifolium	*repens*	Fabaceae	White clover
Triglochin	*palustre*	Juncaginaceae	Marsh arrow-grass
Trillium	*sessile*	Liliaceae	Sessile trillium
Triosteum	*perfoliatum*	Caprifoliaceae	Common horse-gentian
Typha	*latifolia*	Typhaceae	Common cattail
Ulmus	*americana*	Ulmaceae	American elm
Ulmus	*rubra*	Ulmaceae	Slippery elm
Valerianella	*umbilicata*	Valerianaceae	Navel-fruited cornsalad
Verbena	*hastata*	Verbenaceae	Common vervain
Verbena	*urticifolia*	Verbenaceae	White vervain
Verbesina	*alternifolia*	Asteraceae	Wingstem
Vernonia	*gigantea*	Asteraceae	Tall ironweed
Veronica	*anagallis-aquatica*	Scrophulariaceae	Water speedwell
Viburnum	*lentago*	Caprifoliaceae	Nannyberry
Viburnum	*opulus*	Caprifoliaceae	High-bush cranberry
Viburnum	*prunifolium*	Caprifoliaceae	Black-haw
Viola	*cucullata*	Violaceae	Blue marsh violet
Viola	*palmata*	Violaceae	Three-lobed violet
Viola	*pubescens*	Violaceae	Yellow violet
Viola	*sororia*	Violaceae	Common blue violet
Vitis	*riparia*	Vitaceae	Riverbank grape
Vitis	*vulpina*	Vitaceae	Frost grape
Zizia	*aurea*	Apiaceae	Golden-Alexanders

Appendix 4. Floristic Quality Data.

FLORISTIC QUALITY DATA

Native Species	**246**
Adventive Species	**41**
Total Species	**287**
Native FQI	**61.9**
All Species FQI	**57.3**
Native Mean C	**3.9**
All Species Mean C	**3.4**

Plants with a C value of 8, 9, or 10
(C is the coefficient of conservatism)

Plants with a C value of 8:
Aureolaria virginica
Carex leptalea
Phlox maculata
Rudbeckia fulgida var. *sullivantii*
Solidago patula

Plants with a C value of 9:
Carex *sterilis*
Carex tetanica
Dasiphora fruticosa var. floribunda
Filipendula rubra
Lysimachia quadriflora
Oligoneuron riddellii
Viola cucullata

Plants with a C value of 10:
Carex buxbaumii
Carex cryptolepis
Eleocharis elliptica
Lobelia kalmii
Muhlenbergia glomerata
Parnassia glauca
Ranunculus hispidus var. *caricetorum*
Rhynchospora capillacea
Solidago uliginosa
Spiranthes lucida
Taxodium distichum *
Triglochin palustre
Symplocarpus foetidus

* *Taxodium distichum* occurred at the site. However, it was planted and has not naturalized. Thus, it was not used in FQI analysis.

Native Physiognomic Summary

Plant Type	Number	% of Total
Native	246	85.7%
Tree	27	9.4%
Shrub	19	6.6%
Woody Vines	8	2.8%
Herbaceous Vines	5	1.7%
Perennial Forbs	111	38.7%
Biennial Forbs	6	2.1%
Annual Forbs	19	6.6%
Perennial Grasses	16	5.6%
Annual Grasses	1	0.3%
Perennial Sedges	27	9.4%
Annual Sedges	0	0.0%
Ferns	7	2.4%

Adventive Physiognomic Summary

Plant Type	Number	% of Total
Adventives	41	14.3%
Tree	2	0.7%
Shrub	6	2.1%
Woody Vines	1	0.3%
Herbaceous Vines	0	0.0%
Perennial Forbs	11	3.8%
Biennial Forbs	4	1.4%
Annual Forbs	6	2.1%
Perennial Grasses	9	3.1%
Annual Grasses	2	0.7%
Perennial Sedges	0	0.0%
Annual Sedges	0	0.0%
Ferns	0	0.0%

Appendix 5. Non-metric Multidimensional Scaling.

Correlation coefficient with the two axes.

	Q Axis 1	Q Axis 2
ASTPUN	43.85512	59.33433
CARBUL	46.07237	67.722
CARHYS	35.18952	73.96676
CARLEP	58.08545	17.91793
CARLUR	40.21019	56.40807
CARSTR	43.50189	56.99415
CORAMO	93.64898	24.65053
ELEELL	83.69732	19.89773
ELEERY	94.23898	25.38911
EQUARV	65.90025	26.43762
EQUHYM	26.36535	41.91030
EUPPER	27.33755	64.49530
FILRUB	61.24046	63.20743
GALTRI	68.48822	29.74322
GLYSTR	41.58264	81.29607
IMPCAP	38.58621	63.53670
IRIVIR	42.15240	12.03545
LEEORY	33.55241	60.57782
LYCAME	76.62562	29.44089
LYCUNI	49.86877	38.73254
MUHFRO	61.46957	20.22131
PEDLAN	46.15057	10.82837
PILFRO	50.89565	51.93257
POLPUN	40.21019	56.40807
RUDHIR	97.80954	29.53155
RUMOBT	48.23932	62.35656
SCHSCO	59.22224	0
SCIATR	27.92809	33.30678
SELAPO	94.59493	25.75935
SENAUR	63.62613	23.15402
SOLDUL	45.80171	60.55050
SORNUT	73.27486	8.580002
SYMFOE	58.75583	70.73589
TYPLAT	54.30218	67.04790
VIOCUC	64.42226	27.72208

	Q Axis 1	Q Axis 2
PLOT11	25.71138	15.37519
PLOT12	52.71593	15.59180
PLOT13	59.22224	0
PLOT21	100	32.07277
PLOT22	94.23898	25.38911
PLOT23	87.22414	17.09703
PLOT31	60.28138	71.99948
PLOT32	52.02423	65.16105
PLOT33	40.21019	56.40807
PLOT41	33.28995	100
PLOT42	8.054286	86.78290
PLOT43	0	72.28247